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ELECTRONIC STOPPING POWER CALCULATIONS FOR ALL HEAVY IONS AT LOW VELOCITY IN ALL ELEMENTS

BY J. G. BRENNAN D. J. LAND

RESEARCH AND TECHNOLOGY DEPARTMENT

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Values of the electronic stopping power for projectiles from carbon to uranium in elemental targets from hydrogen through the transuranic elements at the Bohr velocity, $v_0 = e^2/\hbar$, are presented in sets of tables. The stopping powers were calculated within a modified Firsov model. An algorithm for determining the stopping power from v=0 to v=3 to $4v_0$ is discussed. The stopping powers, as obtained from this algorithm, are compared with an extensive collection of experimental data. The results are presented in a series of graphs.

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FOREWORD

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B. F. DE SAVAGE
By direction

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I. INTRODUCTION

This report presents the results of some theoretical investigations to determine methods of calculating the electronic stopping power of low-velocity, heavy ions in all elemental target materials. Our main result has been to use the Firsov model,[1] modified to employ Hartree-Fock wave functions which reflect the atomic structure of the free atom, in determining S_e for all projectiles from carbon through uranium in all elemental targets from hydrogen through the transuranic elements. Tables of these values for S_e at $v=v_o$ ($v_o=e^2/\hbar=2.1877 \times 10^8$ cm/sec) are presented in this report. Part of these results have been previously published[2] but are included here for completeness. In the course of our investigations we have tried to apply this basic model, with additional modifications, such as varying the charge states of the projectile, to determine S_e for all projectile velocities to about $v=3$ to $4v_o$. But no consistent method which gave results that agreed with experimental data could be found. We have therefore proposed to use the scaling law for stopping powers at higher velocities, $v=2$ to $3v_o$, the modified Firsov model with S_e

[1] O. B. Firsov, Zh. Eksp. Teor. Fiz. 36, 1517 (1959) [Sov. Phys.-JETP 36, 1076 (1959)].

[2] D. J. Land and J. G. Brennan, Atomic Data and Nuclear Data Tables 22, 235 (1978).

velocity proportional to apply for $v=v_0$, and a straight line extrapolation between. Comparisons have been made of the results of this algorithm with as many data sets, which are in themselves extensive, that were known to us. The results of these comparisons are presented in a series of graphs. Comparisons with the Lindhard-Scharff model[3] for S_e are also shown. This collection of data is of considerable interest in itself. Our algorithm shows generally good correlation with the data. The conclusion contains a discussion of some of the theoretical problems associated with this method.

The need to know accurate stopping powers arises in many contexts. Ion implantation has become an important technique for altering the surface of materials in connection with device fabrication and in improving their resistance to wear and corrosion. Another example consists of the study of the radiation damage produced by the interaction of particles with the containment walls of nuclear reactors. A third example concerns the increasing use of ions heavier than helium in surface layer analysis. The present work is intended to provide more accurate values for electronic stopping powers for all projectile and target atoms than is presently available from the low-velocity statistical theories.

[3] J. Lindhard and M. Scharff, Phys. Rev. 124, 128 (1961).

II. ANALYSIS

The electronic stopping power S_e for projectiles with velocity $v \leq Z_1^{2/3} v_o$ is frequently obtained from the well-known formula of Lindhard and Scharff,

$$S_e = \xi 8\pi e^2 a_o (Z_1 Z_2 / Z)(v/v_o) \quad , \tag{1}$$

where Z_1 and Z_2 are the atomic numbers of the projectile and target, respectively, $\xi = Z_1^{1/6}$, $Z = \left(Z_1^{2/3} + Z_2^{2/3}\right)^{3/2}$, and a_o is the Bohr radius ($a_o = \hbar^2/me^2$). There is a second result for S_e which is also widely used, first written by Teplova[4] et. al. and based on a model of Firsov for the average excitation energy as a function of impact parameter in a collision involving heavy ions:

$$S_e = 5.15 \times 10^{-15} (Z_1 + Z_2)(v/v_o). \tag{2}$$

This form is restricted to projectile and target combinations whose atomic numbers do not differ by more than a factor of four. Both of these models use the Thomas-Fermi free atom densities. While the Lindhard-Scharff result in particular produces reasonable values for S_e throughout the periodic table, neither form explains certain features of the experimental data. The data show that S_e is a

[4] A. Teplova, V. S. Nikolaev, I. S. Dmitriev, and L. N. Fateeva, Zh. Eksp. Teor. Fiz. 42, 44 (1961) [Sov. Phys.-JETP 15, 31 (1962)].

periodic function of either Z_1 or Z_2 for constant projectile velocity, in contrast to the predictions of Eqs. (1) and (2) which indicate a smooth behaviour. The data also shows that, for many projectile-target systems, S_e is not a linear function of velocity in the low-velocity region, as is predicted by Eqs. (1) and (2). Improvements in the models are required to obtain values for S_e of greater accuracy.

The present tables relate mainly to the dependence of S_e on Z_1 or Z_2. The observed periodic structure of S_e on Z_1 or Z_2 has been attributed to a corresponding periodic structure in the atomic densities. The use of wave functions which incorporate the effects of atomic structure, such as Hartree-Fock wave functions,was first suggested by Chesire and Poate and by Bhalla, Bradford, and Reese in calculations of S_e within the context of a modified Firsov model.[5,6] Good qualitative results pertaining to the Z_1 dependence were achieved in calculations for differing projectiles in carbon, particularly as regards the positions of the maxima and minima of the stopping-power curves. These data were taken at Aarhus. In a second application relevant to the Z_2 dependence, the modified Firsov model was successfully used to correlate values of S_e inferred from measurements of range distributions made at the Naval Surface Weapons Center for 800 keV nitrogen ions in a wide variety of target materials.[6-8] Thus the agreement for both a Z_1 and Z_2 dependence is quite satisfactory.

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[5] I. M. Chesire and J. M. Poate, in Atomic Collision Phenomena in Solids, edited by D. W. Palmer, M. W. Thompson, and P. D. Townsend (North-Holland Amsterdam, 1970), p. 351; C. P. Bhalla, J. N. Bradford, and G. Reese, ibid, p. 361.

[6] D. J. Land, and J. G. Brennan, Nucl. Instrum. Methods 132, 89 (1976).

[7] D. J. Land, J. G. Brennan, D. G. Simons, and M. D. Brown, Phys. Rev. A 16, 492 (1977).

[8] D. G. Simons, D. J. Land, J. G. Brennan, and M. D. Brown, Phys. Rev. A 12, 2383 (1975).

With this success it was of interest to apply the modified Firsov model generally throughout the periodic table to obtain improved values of S_e over those predicted by Eqs. (1) or (2). In the present authors' view this model has distinct advantages in that the structure of the projectile ion as well as that of the target atom can be taken into account, including the possibility of considering different charge states for the projectile.[9] However, this model has the disadvantage that its physical basis is somewhat obscure and consequently it is difficult to establish corrections on a fundamental level. Nevertheless, the Firsov model with the Thomas-Fermi atomic densities leads to values for S_e which are close to those predicted by the Lindhard-Scharff result of Eq. (1). If the Firsov model is evaluated with the Firsov plane placed at the potential minimum, reasonable agreement between these models is obtained without a restriction on the projectile and target numbers. Because of this consistency and because of the successful correlation with experimental data, we conclude that the modified Firsov model provides values for S_e which are more accurate than any which are currently available.

In the modified Firsov method the stopping is calculated from the expression,

$$S_e = 2/3\ \pi^2 m_e v \sum_{i} \sum_{nl} \alpha_i^{-3}\ \omega_i^{nl}\ v_i^{nl} \times \int_{\alpha_i b_o}^{\infty} dr\ r \left(r^2 - \alpha_i^2\ b_o^2\right)^{3/2} \rho_i^{nl}(r), \tag{3}$$

[9] J. G. Brennan, D. J. Land, M. D. Brown, and D. G. Simons, Nucl. Instrum. Methods 149, 143 (1978).

in which the summations are over projectile and target atoms(i) and over the electronic orbitals (nl) of each; ω_i^{nl} is the electron occupation number of the ith orbital, v_i^{nl} the electronic velocity, ρ_i^{nl} the electronic density, α_i the fractional position of the Firsov plane which divides projectile and target atoms, and b_o is the minimum impact parameter. The position of the Firsov plane is located at the potential minimum for each projectile-target system when the two particles are at the separation b_o. The electronic velocities and densities were obtained for the ground state of the singly ionized atomic projectile in the range $Z \leq 54$, from the wave functions given in the tables of Clementi and Roetti.[10]

For atoms whose atomic number is greater than 54, relativistic corrections are known to be significant in some applications. We obtained the relativistic wave functions from J. Mann of Los Alamos Scientific Laboratory (LASL) and calculated stopping powers using these functions for target atomic densities, $Z_2 \geq 54$. A comparison of these results with those obtained by using non-relativistic Hermann-Skillman wave functions[11] show that, although contributions from individual electronic shells might differ by as much as 20%, the stopping power of the target differed by less than 5%. For projectile ions, $Z_1 \geq 55$, we used the Hermann-Skillman wave functions. Stopping power values for such heavy projectiles at low velocity are of less practical importance and would not justify the use of

[10] E. Clementi and C. Roetti, Atomic Data and Nuclear Data Tables 14, 177(1974).

[11] F. Herman, S. Skillman, Atomic Structure Calculations, (Prentice Hall Inc., Englewood Cliff, New Jersey, 1963).

relativistic ionic wave functions which would have required much more computer time. In addition, the uncertainty in the exact nature of the charge-state distributions of the projectile introduces greater uncertainty in the stopping power values than does the absence of relativistic corrections. In summary our tables have been calculated using relativistic atomic wave functions for $Z_2 \geq 54$, but using non-relativistic ionic wave functions for the entire range of Z_1.

In order to correlate the model predictions with the data, it is necessary to consider b_o, the minimum impact parameter, as a parameter of the theory. The value of this parameter was chosen to give the best correlation for the nitrogen data and was found to be 2.11 a.u. This is the value used in the calculations reported here.

While generally good agreement of the predicted values of S_e with experimental values is obtained, systematic discrepancies are noted for light projectiles. For lithium projectiles we require the larger value of 2.7 a.u. to correlate the data, and for incident protons we need a much larger value just to get rough numerical agreement. The functional dependence on Z_2 in this case is poor. We conclude that this model is not useful for light projectiles and hence we limit the results to projectiles having $Z_1 \geq 6$. For target atoms we do not find a similar restriction. However, recent work at NSWC using nitrogen projectiles on tantalum, gold and lead targets do not seem to be in agreement with the predictions of the theory, especially with the predicted minimum of S_e for the gold target. It may be found that the theory breaks down for very heavy target atoms but no conclusions can be drawn at this time with so few data points.

While there is no reason that b_o should be constant, as we have assumed here, the correlation with the data, apart from the exceptions noted, suggests that this is a reasonable and useful working hypothesis.

An important consideration concerns the region of projectile velocity and energy for which these results are applicable. While there is experimental evidence that S_e is not velocity-proportional even at low velocity ($v \leq v_o$), the data can be correlated reasonably well in this region by assuming a linear dependence on velocity. But for $v > v_o$, sharp breaks from linearity frequently are observed. This is discussed in Ref. (9) in which variable projectile charge states were considered within the modified Firsov model in an attempt to find a model for S_e applicable to a wider velocity region. We concluded that the modified Firsov model in general can produce reasonable values for S_e only for $v \leq v_o$ with the assumption of velocity-proportional stopping.

However, values of S_e at $v=v_o$ which do reflect the observed period structure at lower velocities can be used to construct S_e for higher velocities. At sufficiently high velocities the electronic stopping for heavy ions can be related to the stopping for protons by means of the scaling law,[12]

$$S_{e,Z}(v) = (\gamma Z_1/\gamma_p)^2 \; S_{e,p}(v), \qquad (4)$$

where $S_{e,p}(v)$ and $S_{e,Z}(v)$ are the stopping powers of incident proton and heavy ion (atomic number Z) projectiles, respectively, at the same

[12] L. C. Northcliffe and R. F. Schilling, Nuclear Data A 7, 233, (1970).

velocity and where γ_p and γ are the effective fractional charges of the proton and heavy ion, respectively (both functions of the velocity). This law can be used for velocities higher than some value, say v_c. For velocities between v_o and v_c, the stopping can be obtained by connecting with a straight line the stopping at $v=v_o$ with the stopping given by the scaling law at $v=v_c$. Below $v=v_o$ the stopping is found from the value at v_o assuming velocity proportionality. This simple algorithm generally proves quite useful.

The physical explanation of the scaling law may be viewed as follows. As the velocity of the projectile is increased it loses more electrons. At some velocity v_c above v_o, the projectile has lost all of those electrons which give to S_e a periodic structure at low velocities. Above v_c the ion behaves like a structureless particle with charge (Z_1-n), where n equals the number of electrons which have been removed. Thus the stopping power may satisfy the scaling law above v_c. However, there is evidence that the critical velocity, v_c, is Z_1 dependent. We find for the most systems that this algorithm produces reasonable agreement with the experimental data under the assumption that $v_c \approx 2v_o$. However, the data obtained by using uranium projectiles is fitted better by assuming that $v_c \approx 3v_o$.

An explanation of the Z_1 dependence of v_c can be offered. Suppose that the number of outer electrons, n, which are responsible for structure effects and which are removed if the projectile velocity exceeds v_c, can be quantified as those which make significant

contributions to S_e at $v=v_o$, within the framework of the modified Firsov calculation. To be more specific, we may define, arbitrarily, that these electrons are characterized by the fact that they provide at least 1% of the calculated value of S_e at $v=v_o$. Using this criterion we have determined the number of such outer electrons as shown in Table I. The abrupt changes in n at certain values of Z_1 should not be taken too precisely since a slight change in the arbitrary 1% criterion would shift these transition points. However, if one considers these values as approximately correct, one sees that n increases with Z_1, but does so in an oscillatory manner. Among the heavy projectiles, uranium is seen to have about twice as large an n value as the other heavier ions for which we have data (halogens), which explains qualitatively why one must choose v_c to be larger to accomodate the uranium projectile data. Unfortunately there is a scarity of experimental data for $Z_1 \geq 30$, so the model must remain unproven until more data is available.

III. RESULTS

The values for S_e which have been calculated here are presented in a large set of tables (formally Table III). The electronic stopping power is given at the velocity $v=v_0$. Values are listed in two groups, the first for target atoms with $1 \leq Z_2 \leq 54$, and the second for targets with $55 \leq Z_2 \leq 102$. In Appendix I we give an example of how to use the algorithm to construct a stopping power curve valid at higher velocities.

In order to compare the results of the theoretical algorithm with experimental data, we present in Figures 1-15 a series of graphs showing the data along with theoretical curves representing the modified Firsov prediction joined to the scaling law at higher velocity. The Lindhard-Scharff values of Eq. (1) are also given. These graphs are arranged in a Z_1 versus Z_2 matrix with generally nine to a page and, in total, contain nearly all of the results of systematic studies of low-velocity electronic stopping known to us.

While there is considerable stopping data available, the vast majority relate to a relatively small number of projectiles on a small number of targets. As discussed above, we are not considering the vast amount of data for the lightest projectiles. Extensive data sets exist for projectiles with $Z_1 \leq 20$ in a standard set of elemental targets, which include carbon, aluminum, nickel (and

sometimes copper), silver and gold.[13] Extensive data also exists for light projectiles ($Z_1 \leq 13$) in the noble gases[14] (excluding radon) and in nitrogen and air.[15] The remaining extensive data sets include the halogen projectiles, chlorine,[16] bromine and iodine, and uranium projectiles[17] in the standard solid targets. There is, of course, numerous data for isolated Z_1 in Z_2. Data of the Chalk River group (Macdonald, Ormrod and Duckworth)[18] include boron targets. Data from Aarhus includes projectiles up to yttrium in carbon. Data from NSWC for nitrogen projectiles on many solid targets through tellurium is also available.

Recent data from Chalk River (Ward et al.)[19] for projectiles $6 \leq Z_1 \leq 20$ in the standard solid targets at $v \simeq v_o$ show an interesting

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[13] B. Fastrup, P. Hvelplund, and C. A. Sautter, K. Dan. Vidensk. Selsk. Mat.-Fys. Medd. 35, No. 10 (1966); P. Hvelplund and B. Fastrup, Phys. Rev. 165, 408(1968). D. I. Porat and K. Ramavataram, Proc. Phys. Soc. Lond. 77, 97(1960); Proc. Phys. Soc. Lond. 78, 1135(1961); J. H. Ormrod and H. E. Duckworth, Can. J. Phys. 41, 1424(1963); J. H. Ormrod, J. R. Macdonald and H. E. Duckworth, ibid. 43, 275(1965).

[14] N. M. Denkin, Ph.D. dissertation, California Institute of Technology (1976).

[15] P. Hvelplund, K. Dan. Vidensk. Selsk. Mat.-Fys. Medd. 38, No. 4(1971). B. Fastrup, A. Borup, and P. Hvelplund, Can. J. Phys. 46, 489(1968).

[16] W. Booth and I. S. Grant, Nuclear Physics 63, 481(1965).

[17] C. D. Moak and M. D. Brown, Phys. Rev. Letters, 11, 284(1963); C. D. Moak and M. D. Brown, Phys. Rev. 149, 244(1966); and M. D. Brown and C. D. Moak, Phys. Rev. B 6, 90 (1972).

[18] J. R. Macdonald, J. H. Ormrod and H. E. Duckworth, Z. Naturforsck. Teil A 27, 130(1966).

[19] D. Ward et. al., Can. J. Phys. 57, 645(1979).

phenomenon concerning the Z_1 oscillations: the amplitude, but not the period, of these oscillations depend upon the target material. The present calculations do not display this feature.

The experimental data are presented following the above outline. First we consider light ions incident on the light and heavy solid targets, Figs. 1-4. Next we show the electronic stopping values for the heavy ions, the halogens and uranium, on light and heavy solid targets, Figs. 5-6. The next set of graphs show the light ions incident on gaseous targets, Fig. 7-10. On the next two pages we display the results of nitrogen projectiles on solid targets, the data from NSWC, Figs. 11-12. This is followed by a set of graphs of electronic stopping of a variety of projectiles incident on carbon, the data from Aarhus, Figs. 13-14. The next page contains some miscellaneous results, Fig. 15. Finally the last two graphs highlight the Z_1 oscillations in carbon and the Z_2 oscillations of nitrogen projectiles at fixed velocity, Figs. 16-17.

Certain observations and conclusions can be deduced from these graphs.

1. In many cases the Lindhard-Scharff values are close to the modified Firsov values at $v=v_o$. However, for the great majority of these cases as well as for those cases where the two theoretical values differ significantly, the modified Firsov value is a closer fit to the data than is the Lindhard-Scharff value.

2. The extrapolation procedure described previously which joint the modified Firsov value at v_o to the scaling law predictions about $2v_o$ seems, in spite of its ad hoc character, to be a very reasonable way of interpreting the majority of the experimental data.

(a) This procedure predicts correctly that the stopping power increases less rapidly than a linear dependence on velocity for carbon projectiles, predicts an approximate linear dependence on velocity for the stopping powers of nitrogen and oxygen projectiles and predicts the observed superlinear velocity dependence of the fluorine, neon and aluminum stopping values.

(b) The method predicts the relationship between the higher velocity stopping values, obtained by Moak and Brown,[17] for halogens and uranium projectiles on the standard solid targets, and the values up to v_o for these cases. Unfortunately, low energy data is available for only one of these cases, that of bromine on carbon, but here, the agreement is quite reasonable.

3. The cutoff in velocity for extrapolating from the scaling law behaviour to the region below v_o is higher for uranium projectiles then is required for the other projectiles for which experimental data are available. To get the best fit to the uranium data, we chose a cutoff of $2.8v_o$ compared to a value of $2v_o$ for all other projectiles that we have shown. As discussed above, it would be very interesting to have data for those projectiles which, like uranium, have a large number of "valence" electrons.

4. The data for aluminum and magnesium ions incident on helium would seem to suggest that these ions are almost entirely doubly ionized even at a velocity of v_o. This is also suggested by the data for magnesium ions incident in air.

[17] See footnote 17 on page 18

5. The good agreement between the experimental values of S_e at $v=v_o$ and the theoretical calculations of the modified Firsov model seems to be independent of whether the target is a solid or a gas. There does seem to be a tendency for the velocity dependence of S_e to be generally superlinear for all projectiles in gas targets (except for helium), whereas the velocity dependence for the corresponding projectiles in solid targets varies from sublinear to superlinear depending on the projectile identity.

In order to estimate the improvement obtained with the present modelling for S_e, we consider several data sets and compute the average of the absolute values for the fractional error between the experimental and theoretical values. That is, if t_i and e_i are the corresponding theoretical and experimental values, respectively, we compute the quantity

$$f = \frac{1}{N} \sum_{i=1}^{N} \left| \frac{t_i - e_i}{e_i} \right| \tag{5}$$

for each data set. We consider the electronic stopping as obtained from the Thomas-Fermi atomic densities, as implemented by Eq. (1) and as given by the set of values reported here, in which we have made use of the receipt described above where the data extends to velocities $v > v_o$. The data sets we have considered along with the fractional errors are listed in Table II. We note that in all cases, the use of Hartree-Fock densities rather than the Thomas-Fermi densities in computing S_e offers improvement in correlating theoretical values with experimental data. The overall unweighted average of the

errors for the six data sets considered is 35% for the Thomas-Fermi density calculations and 17% for the modified Firsov calculations. This, perhaps, may be taken as an indication of the overall error inherent to each model. These data include both solid and gaseous targets. No significant difference in the ability of this model to predict the electronic stopping of solid and gaseous targets can be seen.

IV. GENERAL DISCUSSION AND CONCLUSIONS

This report presents values of the electronic stopping power at the velocity v_o calculated from the Firsov model modified to include realistic atomic structure. These values have been used together with the scaling law for S_e appropriate at higher velocities up to $v=4v_o$. Comparisons of these stopping power curves with a considerable body of experimental data show generally good consistency. We conclude that the model and predictions presented here are the best approximations to experiment available at this time. However, more experimental data are needed to test this model, especially for heavy atoms, $Z \geq 54$, for which very little data exists, with the exception of uranium as a projectile and gold as a target.

Despite the success of this model in correlating data, it has some significant deficiencies. The physical basis and assumptions from which the model is derived are obscure and, consequently, it seems difficult to improve upon the model on a fundamental level in a systematic way. We had noted earlier that the unmodified Firsov model can produce numerical values that are consistent with the predictions of the Lindhard-Scharff model, which in turn correlates with the data in an average sense, with respect to the Z_1 or Z_2 oscillations. However, in implementing the present approach, there are two significant departures from the original model. The first

is the use of the expression for $\left[\langle T\rangle\right]^{1/2}$, where T is the kinetic energy operator, from which the atomic orbital velocities are obtained. This procedure gives the root-mean-square value for the velocity rather than the average velocity given by $v_{ave} = \hbar \langle k\rangle /m$. The other is the use of a non-zero minimum impact parameter, required so that the model does agree with experiment. The root-mean-square formula gives values for the velocity of the outer orbitals which are considerably larger than those obtained from the average velocity. Hence the need for a non-zero b_o. However, the happy result of these circumstances is that considerable weight is given to the contributions to S_e from the outer orbitals from which the periodic structure that is observed in the data arises. Thus the present implementation,which also corresponds to the work of Chesire et. al. and to Bhalla et. al., may be regarded as a physically different model from the original Firsov model. The implications of the use of the average velocity are presently under study by Cruz and his colleagues[20] who are attempting to provide a more concrete physical basis for the Firsov model. A justification for the use of a minimum impact parameter was provided by Denkin.[14] This author suggested that atomic orbitals whose velocities exceed the projectile velocity should not contribute to the stopping, similar to the more familiar argument of an adiabatic limit on the distant collisions for high-velocity projectiles.

[20] S. A. Cruz, C. Vargas and D. K. Brice, 8th International Conference on Atomic Collisions in Solids Hamilton, Canada (1979).

[14] See footnote 14 on page 18

In the present authors' view future efforts on this problem lie more profitably in exploiting the theory of stopping for a free electron gas developed by Lindhard.[21] This model offers several possible treatments of the target, as a free electron gas for conduction electrons in a solid or as a free electron model of the atom, either as free for a gaseous target or as bound for a solid target. It also allows the inclusion of projectile structure. Initial efforts in this direction by Ritchie and his co-workers[22] applied to date only for light projectiles, p and He, are quite promising. Furthermore, this basic model allows for systematic improvements. Further research in this direction is continuing.

[21] J. Lindhard, K. Dan. Vidensk. Selsk. Mat.-Fys. Medd. 28, No. 8(1954).

[22] T. L. Ferrell and R. H. Ritchie, Phys. Rev. B 16, 115(1977).

APPENDIX A

USE OF TABLE III TO CONSTRUCT STOPPING-POWER CURVES

Table III gives stopping-power values at the velocity v_o. For velocities below v_o, the stopping power can be taken to be proportional to the velocity:

$$S_e(v) = \left(\frac{v}{v_o}\right) S_e(v_o).$$

For velocities above v_o the stopping must be obtained by some other method such as the scaling law of Eq. (4) of the text. To interpolate between a minimum value of velocity for which such a method is applicable and the velocity v_o, a straight line is suggested.

Two examples are presented, carbon in carbon and nitrogen in zirconium. The stopping at $v = v_o$ as found from the tables is 0.70×10^{-13} and 2.03×10^{-13} eV-cm^2, respectively. For velocities above $2v_o$, S_e is obtained from a semi-empirical method developed by Ziegler[23] in which the stopping $S_z(v,Z_2)$ for

[23]J.F. Ziegler, Appl. Phys. Lett. 31, 544 (1977).

any projectile Z having velocity v in a target Z_2 is related to the proton stopping $S_p(v,Z_2)$ by a universal reduced stopping $\langle S \rangle$:

$$\langle S \rangle = \frac{S_Z(v,Z_2)}{Z^2 S_p(v,Z_2)} .$$

The proton stopping is taken from Andersen and Ziegler.[24] The data are from Refs. 10, 16, and 19.

[24] H. H. Andersen and J. F. Ziegler, <u>Hydrogen-Stopping Powers in All Elements</u>, (Pergamon, New York, 1977).

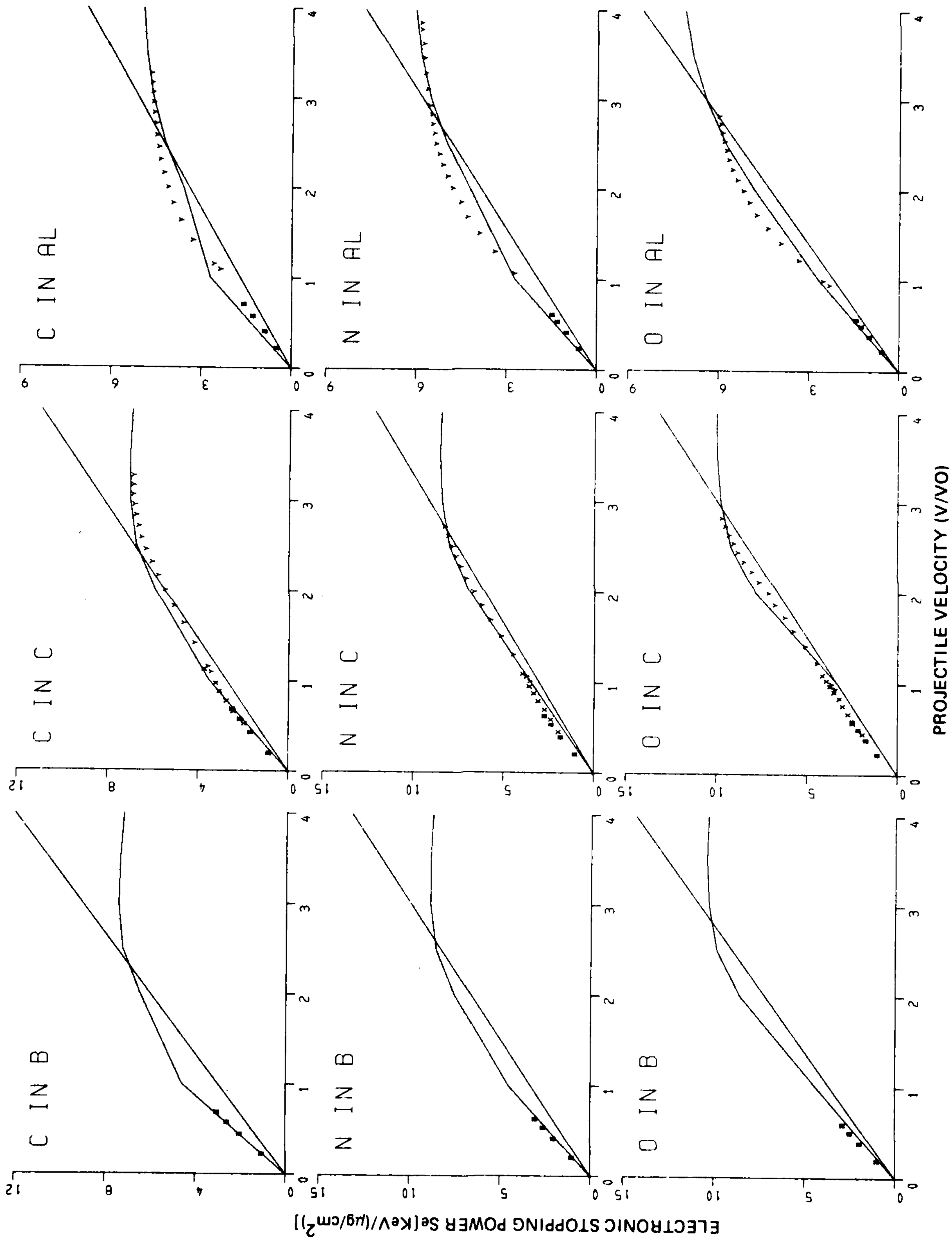

FIGURE 1 ELECTRONIC STOPPING POWER VERSUS PROJECTILE VELOCITY

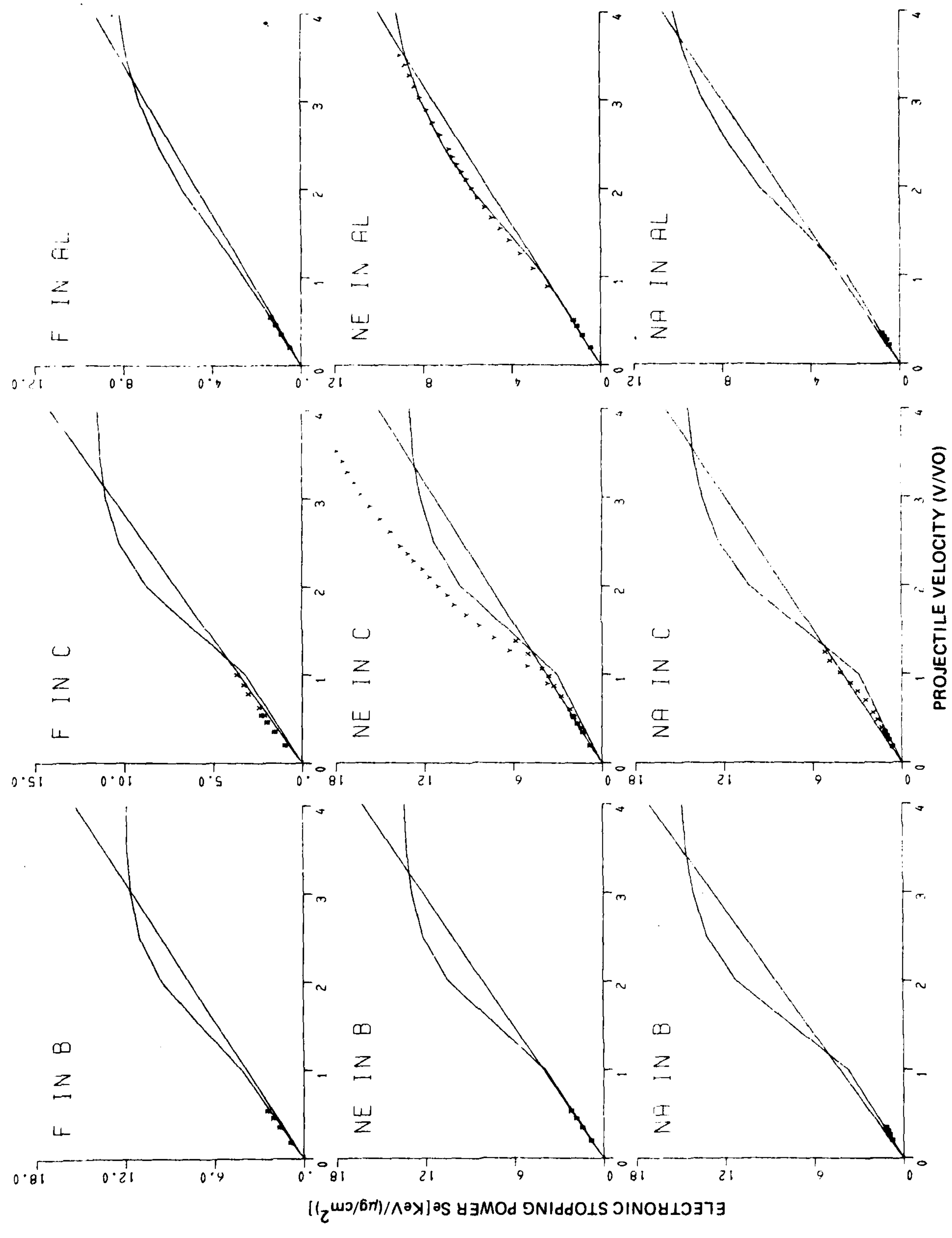

FIGURE 2 ELECTRONIC STOPPING POWER VERSUS PROJECTILE VELOCITY

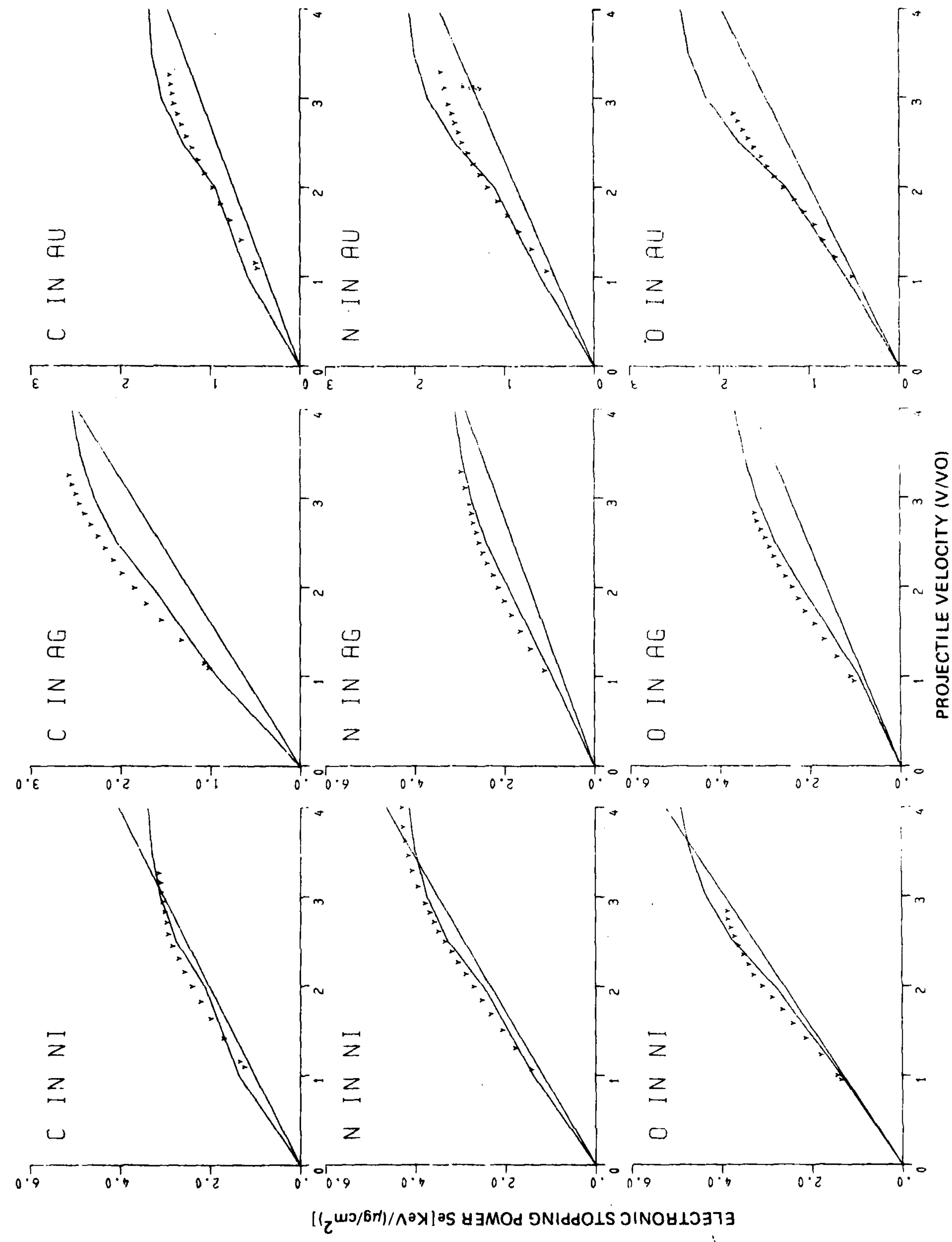

FIGURE 3 ELECTRONIC STOPPING POWER VERSUS PROJECTILE VELOCITY

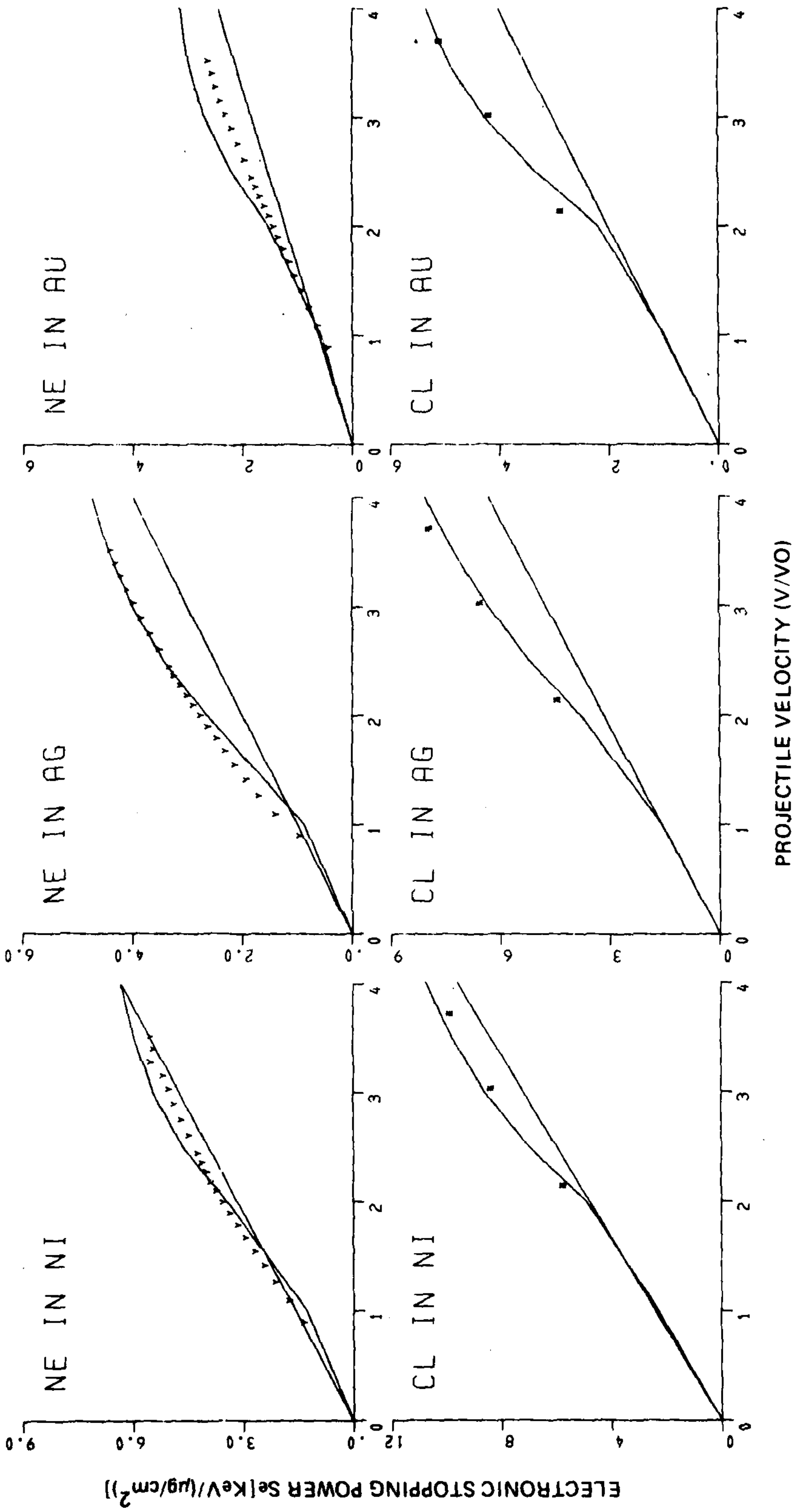

FIGURE 4 ELECTRONIC STOPPING POWER VERSUS PROJECTILE VELOCITY

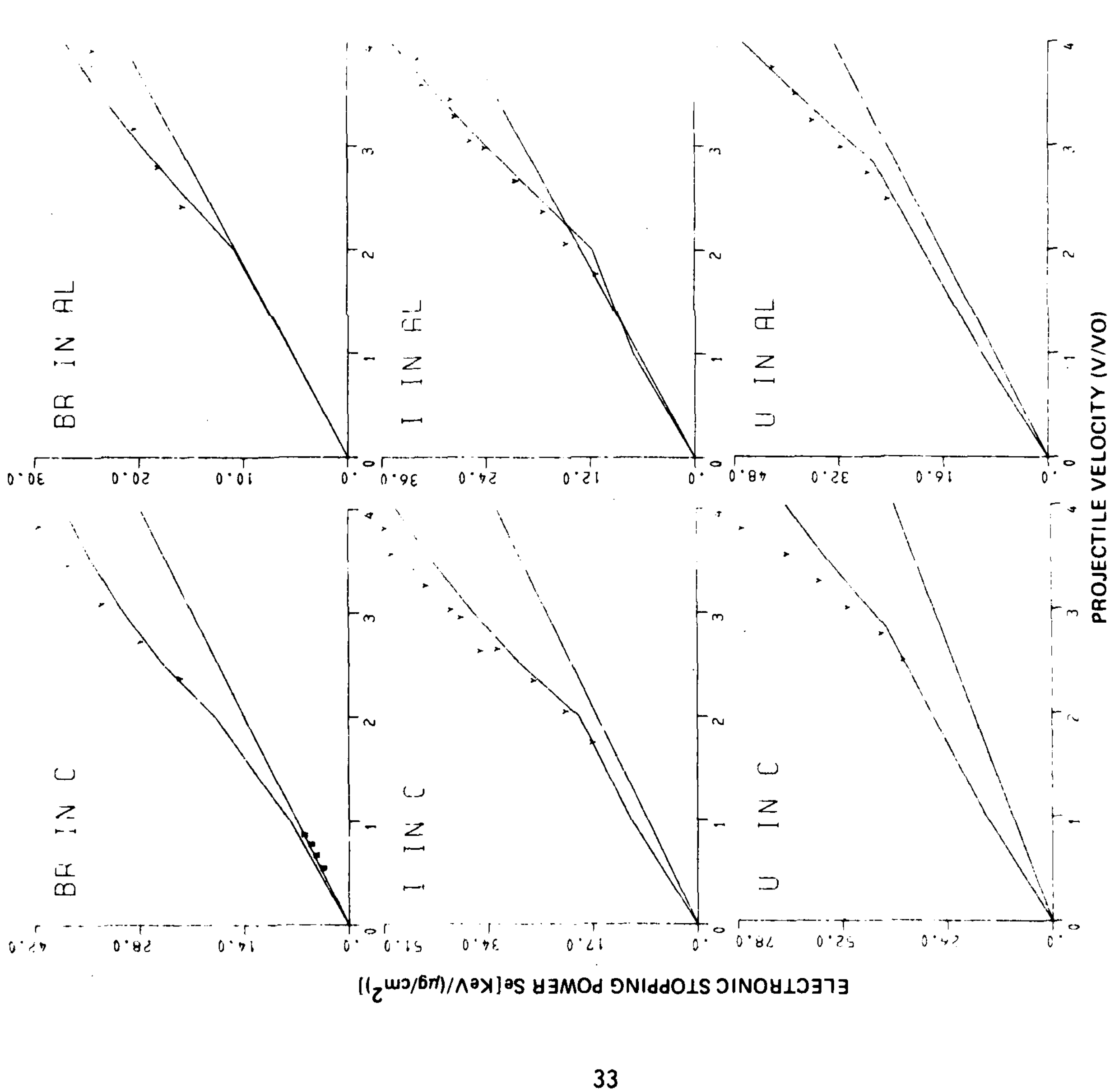

FIGURE 5 ELECTRONIC STOPPING POWER VERSUS PROJECTILE VELOCITY

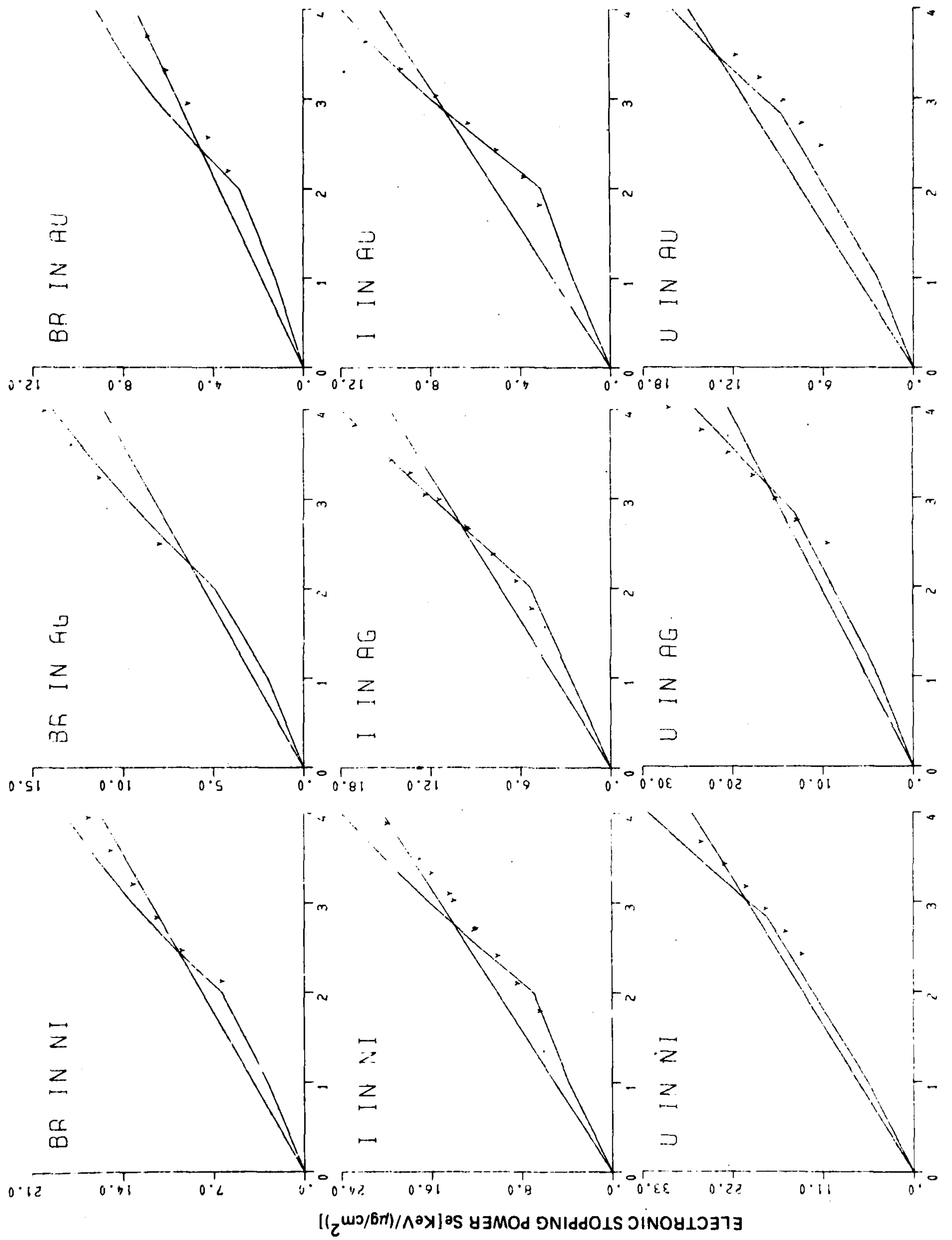

FIGURE 6 ELECTRONIC STOPPING POWER VERSUS PROJECTILE VELOCITY

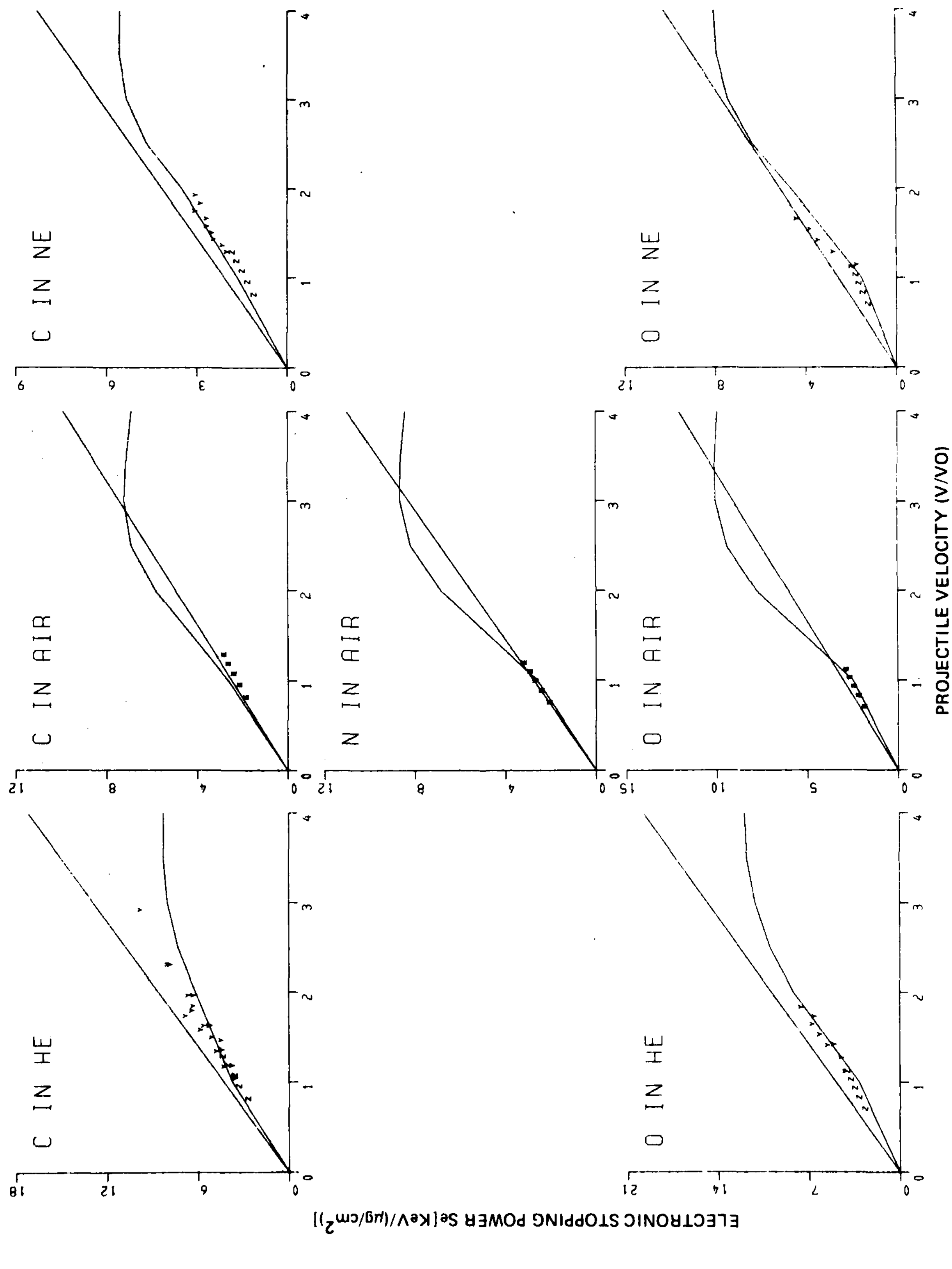

FIGURE 7 ELECTRONIC STOPPING POWER VERSUS PROJECTILE VELOCITY

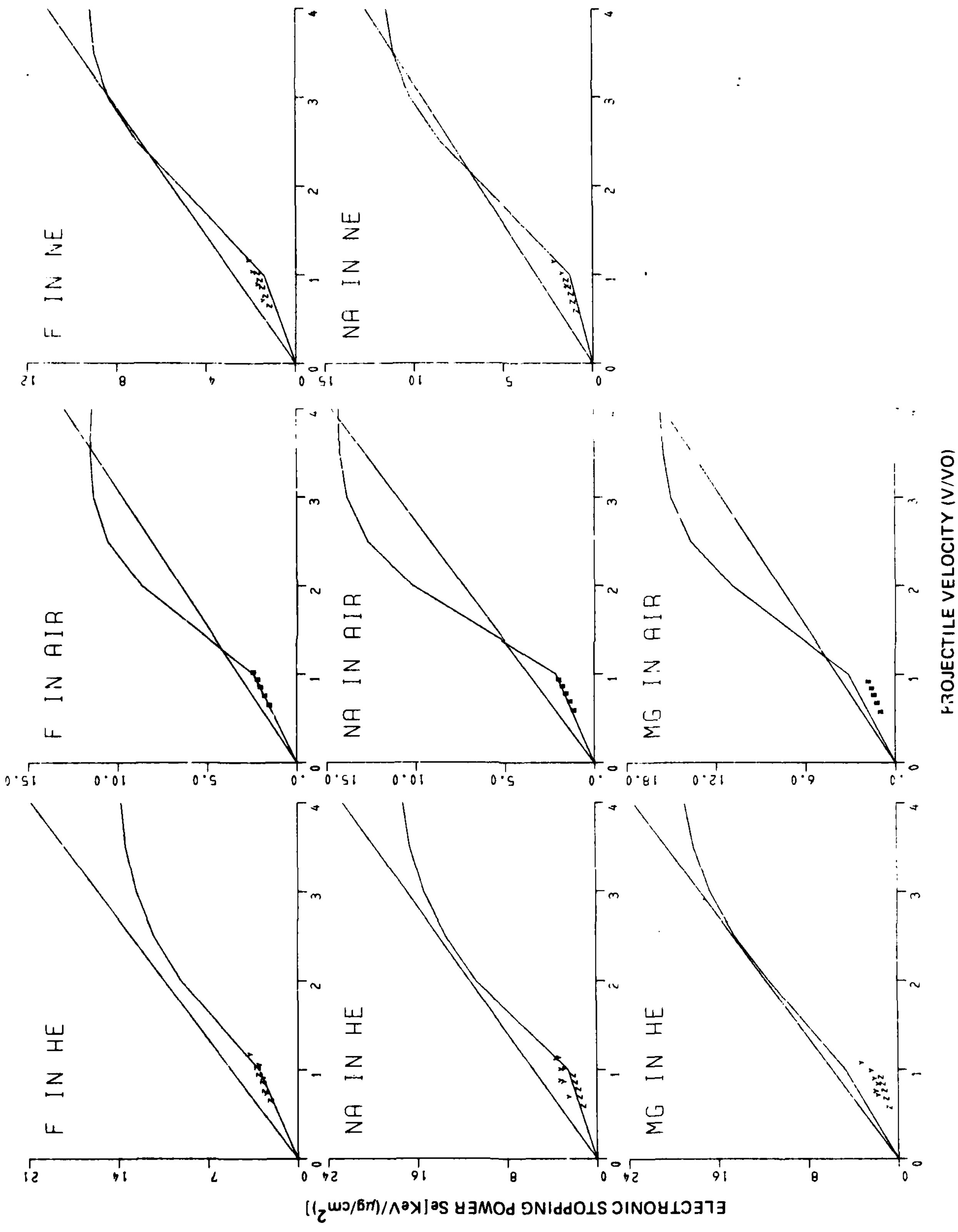

FIGURE 8 ELECTRONIC STOPPING POWER VERSUS PROJECTILE VELOCITY

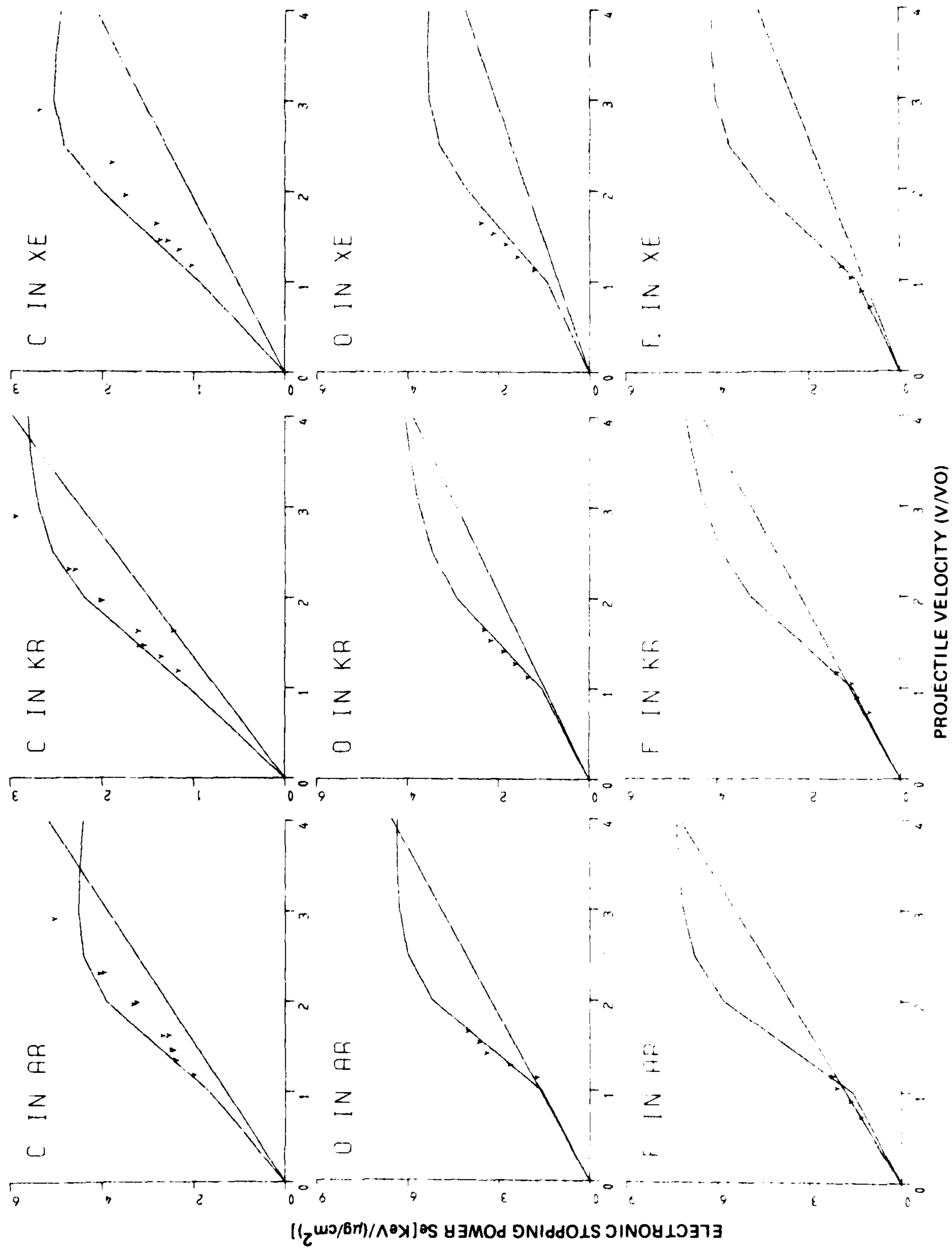

FIGURE 9 ELECTRONIC STOPPING POWER VERSUS PROJECTILE VELOCITY

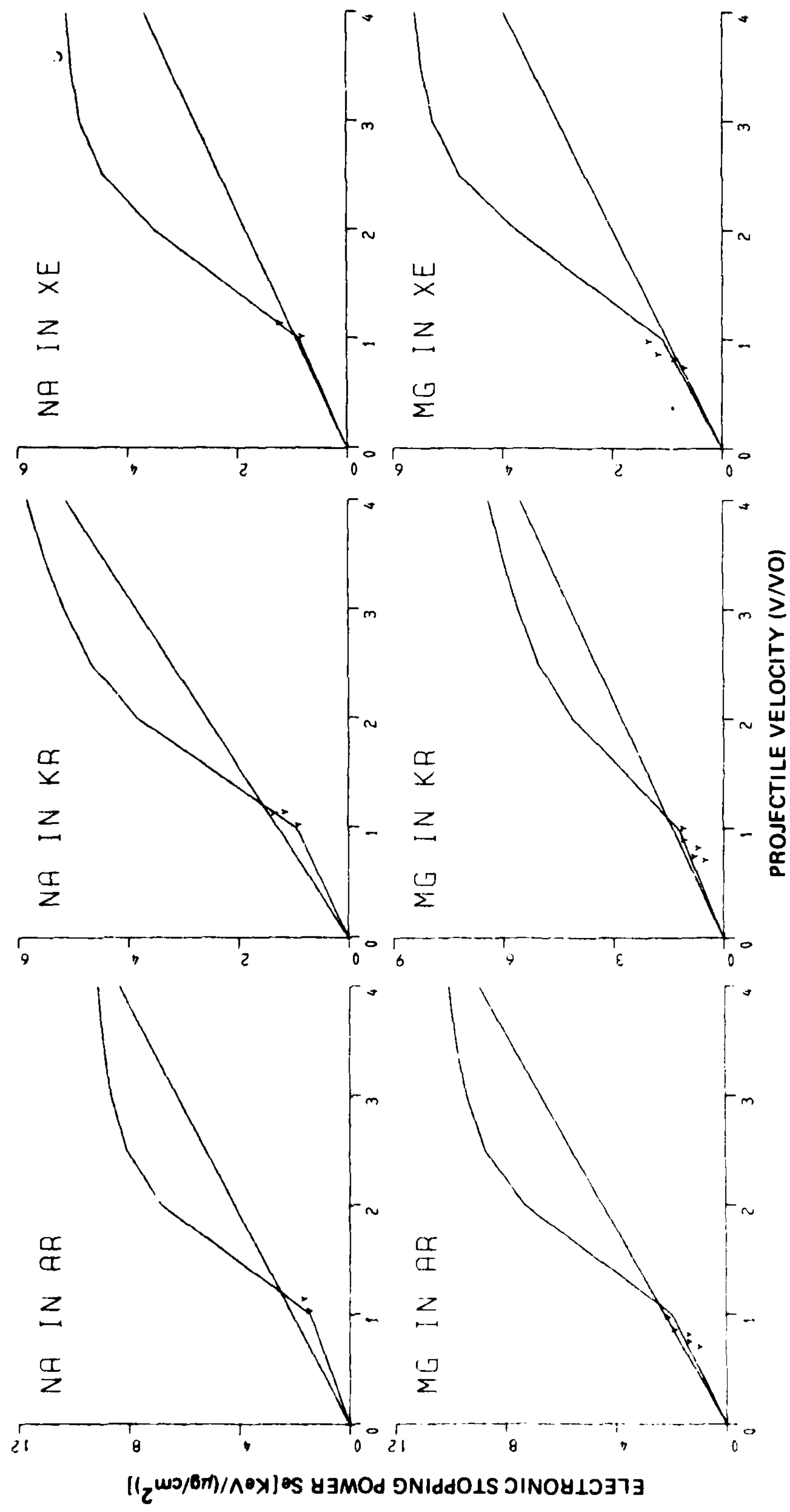

FIGURE 10 ELECTRONIC STOPPING POWER VERSUS PROJECTILE VELOCITY

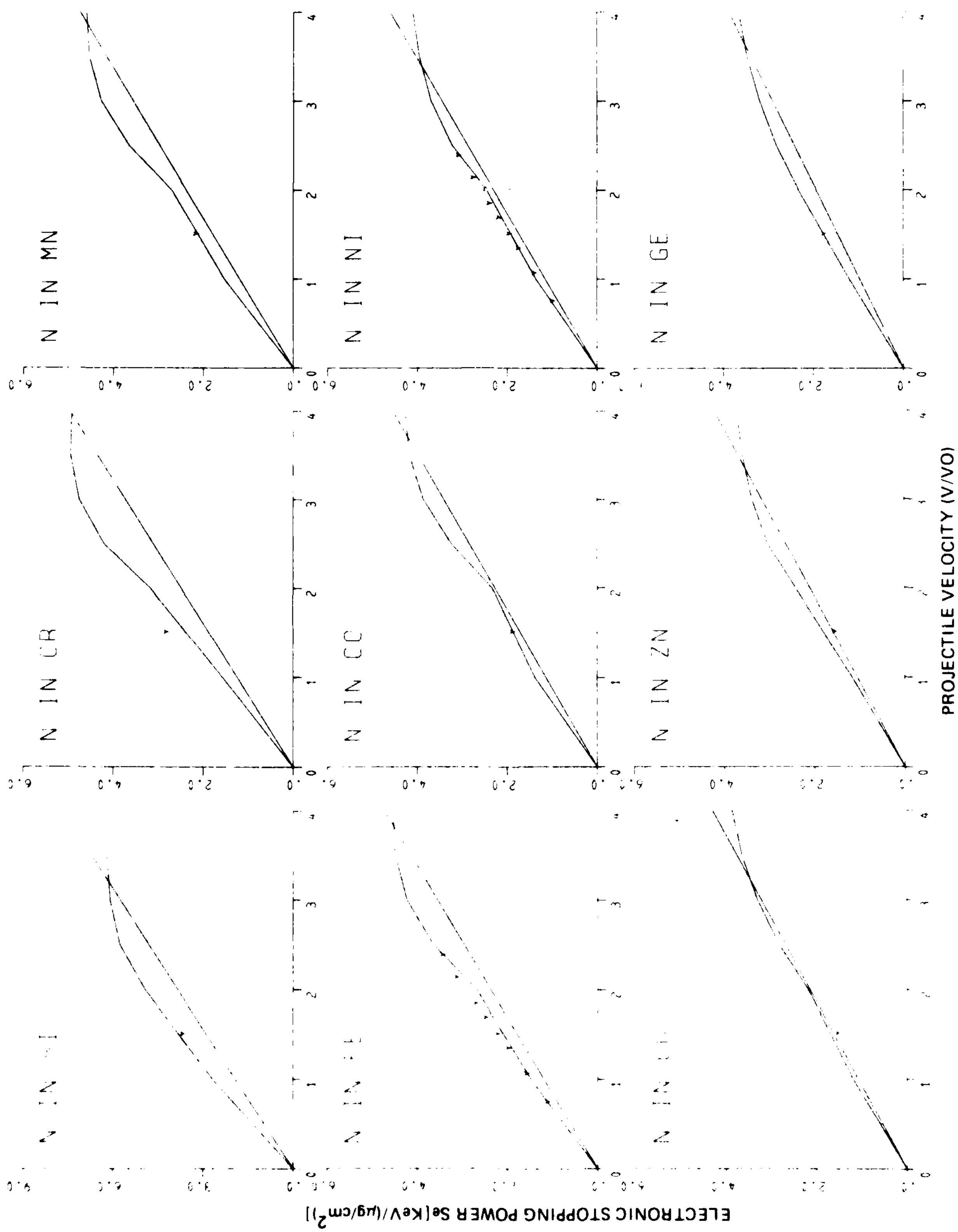

FIGURE 11 ELECTRONIC STOPPING POWER VERSUS PROJECTILE VELOCITY

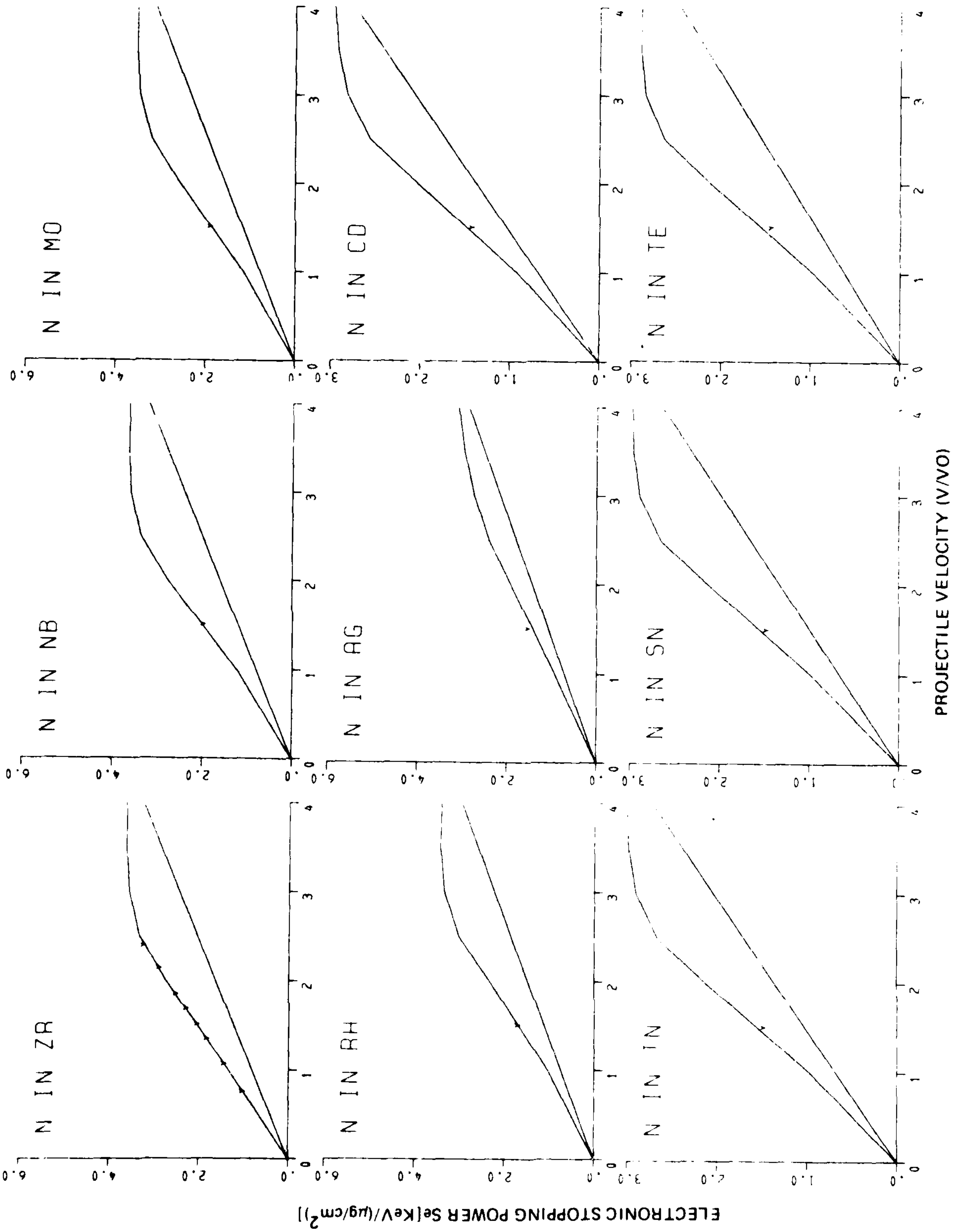

FIGURE 12 ELECTRONIC STOPPING POWER VERSUS PROJECTILE VELOCITY

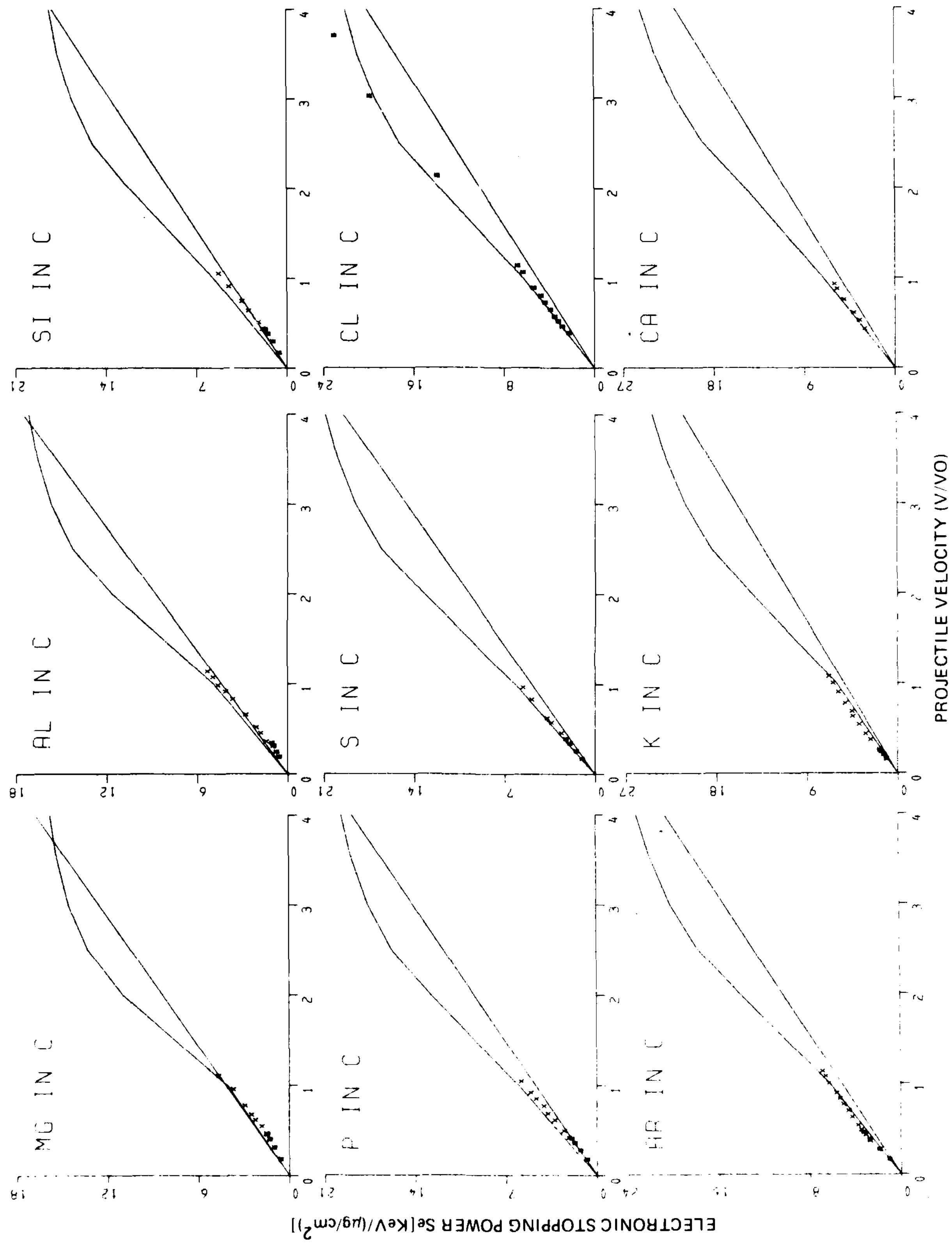

FIGURE 13 ELECTRONIC STOPPING POWER VERSUS PROJECTILE VELOCITY

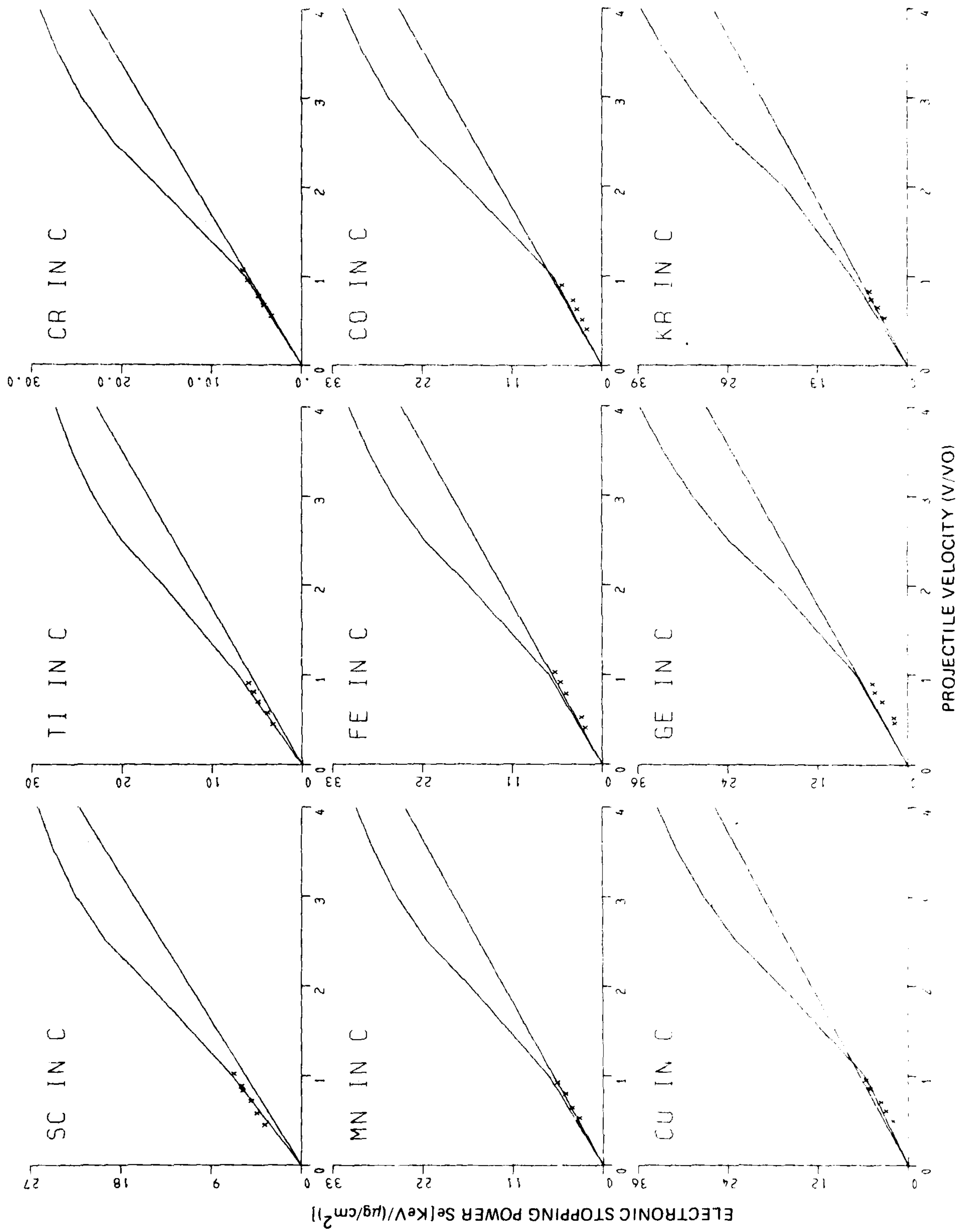

FIGURE 14 ELECTRONIC STOPPING POWER VERSUS PROJECTILE VELOCITY

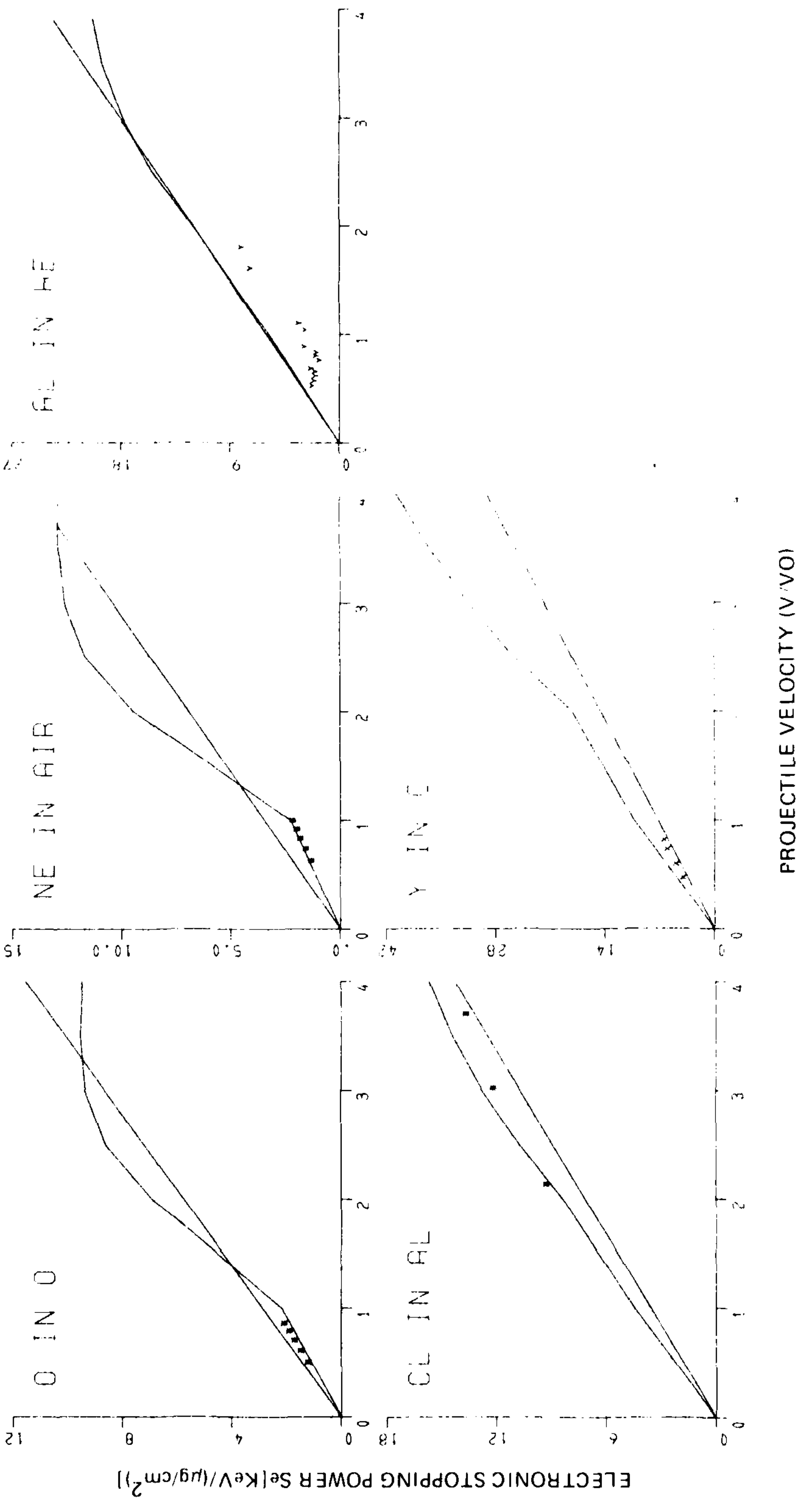

FIGURE 15 ELECTRONIC STOPPING POWER VERSUS PROJECTILE VELOCITY

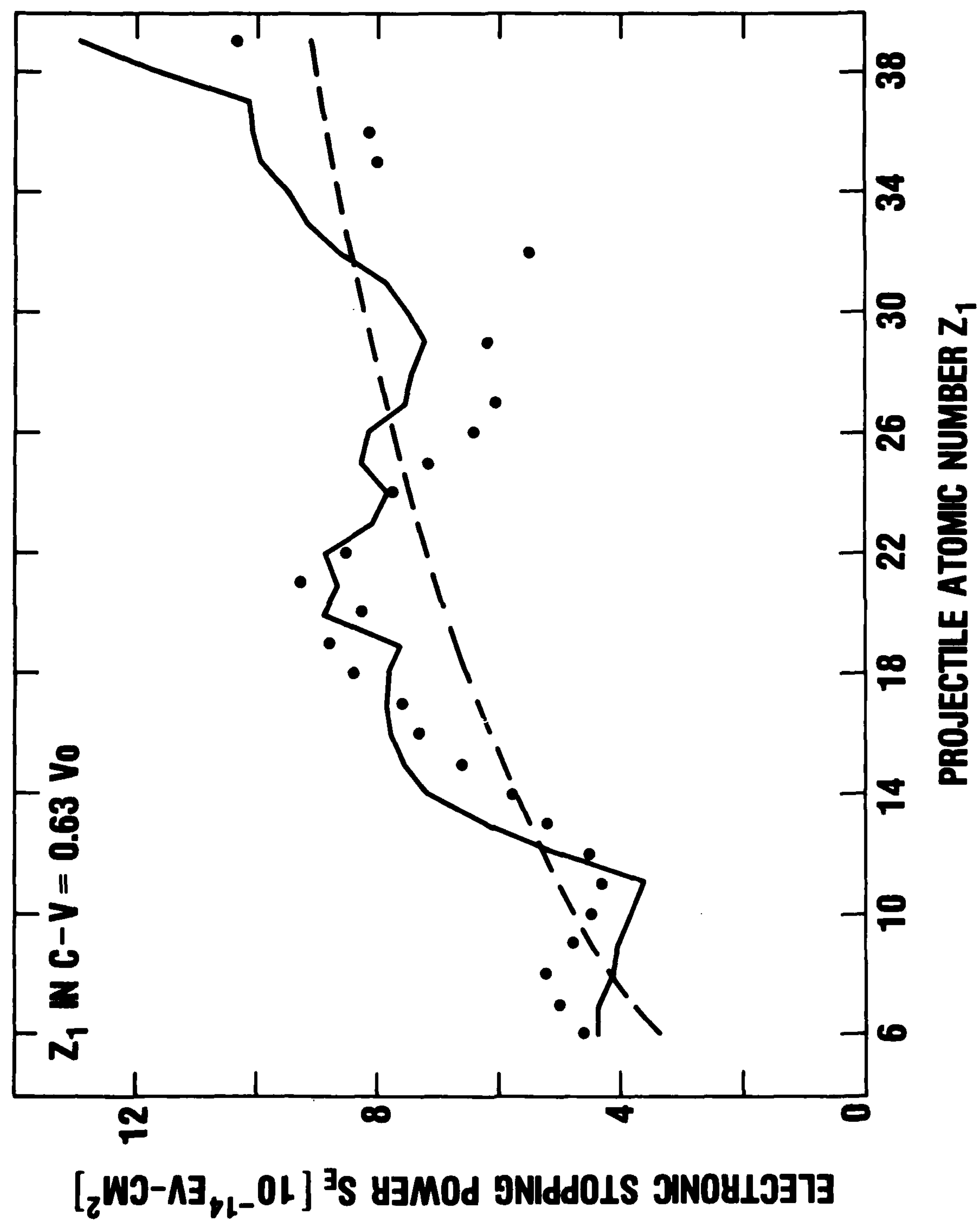

Fig. 16. Electronic Stopping Power Versus Projectile Atomic Number Z_1 - Carbon Target

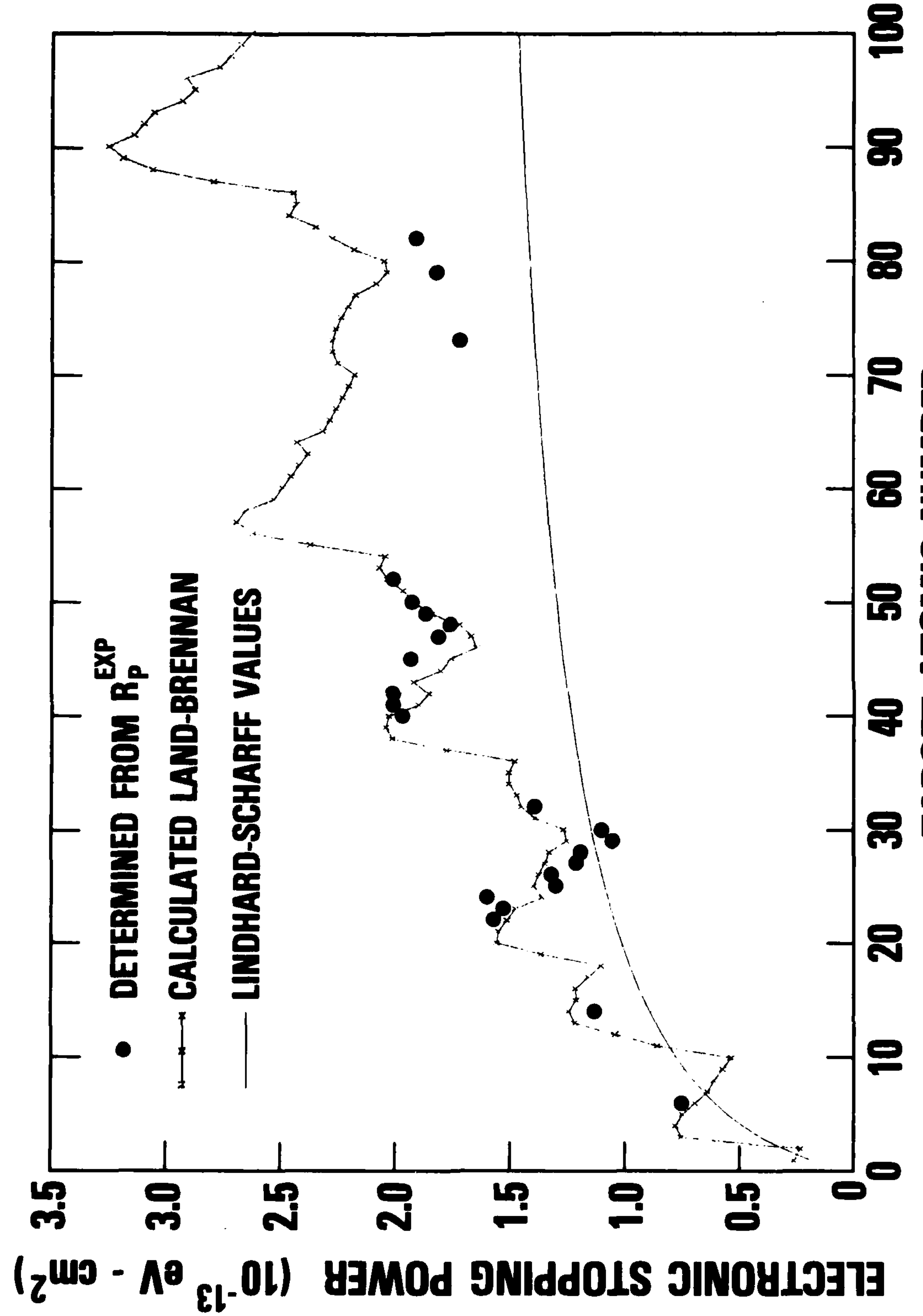

Fig. 17. Electronic Stopping Power Versus Target Atomic Number - Nitrogen Projectiles

TABLE I. OUTER ELECTRONS VERSUS PROJECTILE ATOMIC NUMBER

Z_1	n	Z_1	n
6	3	49	12
7	4	50	13
8	5	51	4
9	6	52	5
10	7	53	6
11	8	54	7
12	7	55	8
13	2	56	9
14	3	57	10
15	4	58	11
16	5	59	10
17	6	60	13
18	7	61	10
19	8	62	9
20	9	63	10
21	10	64	10
22	11	65	10
23	12	66	10
24	11	67	10
25	6	68	10
26	7	69	10
27	8	70	10
28	9	71	10
29	10	72	11
30	11	73	12
31	12	74	13
32	3	75	14
33	4	76	13
34	5	77	14
35	6	78	15
36	7	79	16
37	8	80	11
38	9	81	12
39	10	82	13
40	11	83	14
41	12	84	15
42	13	85	6
43	12	86	7
44	13	87	8
45	8	88	9
46	9	89	10
47	10	90	11
48	11	91	12
		92	13

TABLE II. Comparison of the Average of the Fractional Errors between Theoretical and Experimental Values of the Electronic Stopping Power

Group	Ref.	Experiment	Thomas-Fermi*	Hartree-Fock†
NAVSWC	7,8	800 keV $^{14}N^+$ in Z_2(6-52)	0.26	0.08
Aarhus	13	100-500 keV Z_1(6-39) in C	0.16	0.14
Aarhus	15	100-500 Z_1(6-12) in He, air, Ne	0.53	0.11
Aarhus	15	100-500 KeV Z_1(6-24)in air	0.37	0.29
Cal. Tech.	14	500-1500 keV Z_1(6-13) in noble gases	0.42	0.21
Porat and Ramavataram	13	360-3000 keV Z_1(6-10) in C, Al, Ni, Ag, Au^1	0.17	0.07

*Lindhard-Scharff

†Modified Firsov

TABLE III - ELECTRONIC STOPPING POWER OF IONS AT VELOCITY V0
MODIFIED FIRSOV METHOD   STOPPING POWER (1E-13 EV-CM2)

TARGET ATOMIC NUMBER	PROJECTILE ATOMIC NUMBER 6	7	8	9	10	11	12	13	14	15	16	17	18
1	.28	.26	.24	.23	.21	.19	.33	.42	.49	.53	.53	.53	.51
2	.25	.23	.21	.20	.18	.17	.31	.39	.46	.49	.49	.49	.47
3	.77	.75	.71	.68	.65	.61	.81	.98	1.13	1.23	1.27	1.29	1.27
4	.79	.78	.74	.71	.68	.64	.86	1.03	1.19	1.29	1.34	1.36	1.35
5	.76	.75	.72	.69	.66	.62	.86	1.02	1.17	1.26	1.30	1.32	1.32
6	.70	.69	.66	.64	.61	.58	.82	.98	1.13	1.20	1.23	1.25	1.24
7	.65	.64	.61	.59	.56	.53	.77	.93	1.08	1.14	1.17	1.16	1.17
8	.62	.61	.58	.56	.53	.50	.74	.90	1.04	1.11	1.13	1.14	1.13
9	.59	.57	.54	.52	.49	.46	.70	.86	1.00	1.06	1.08	1.09	1.08
10	.55	.53	.51	.48	.46	.43	.66	.81	.94	1.01	1.02	1.04	1.02
11	.87	.86	.83	.80	.77	.73	.97	1.14	1.31	1.40	1.44	1.46	1.46
12	1.05	1.04	1.01	.98	.94	.90	1.16	1.35	1.53	1.64	1.70	1.73	1.73
13	1.21	1.22	1.19	1.15	1.11	1.06	1.34	1.55	1.75	1.89	1.95	2.00	2.01
14	1.24	1.24	1.21	1.18	1.14	1.09	1.39	1.60	1.81	1.94	2.01	2.07	2.08
15	1.21	1.21	1.18	1.15	1.11	1.07	1.38	1.60	1.81	1.93	1.99	2.04	2.05
16	1.21	1.21	1.18	1.16	1.12	1.07	1.40	1.62	1.84	1.96	2.01	2.06	2.07
17	1.16	1.16	1.13	1.10	1.06	1.02	1.35	1.58	1.80	1.91	1.96	2.00	2.02
18	1.10	1.10	1.07	1.05	1.01	.96	1.30	1.54	1.75	1.86	1.90	1.94	1.93
19	1.36	1.37	1.34	1.31	1.27	1.22	1.57	1.81	2.05	2.17	2.23	2.28	2.29
20	1.54	1.56	1.53	1.50	1.46	1.41	1.76	2.01	2.26	2.40	2.47	2.53	2.55
21	1.54	1.55	1.52	1.50	1.45	1.40	1.75	2.01	2.26	2.39	2.47	2.52	2.54
22	1.50	1.51	1.49	1.46	1.42	1.36	1.72	1.97	2.21	2.35	2.42	2.48	2.49
23	1.46	1.48	1.45	1.42	1.38	1.33	1.67	1.92	2.17	2.30	2.37	2.42	2.44
24	1.35	1.36	1.33	1.31	1.26	1.21	1.55	1.80	2.03	2.16	2.22	2.27	2.28
25	1.39	1.40	1.37	1.34	1.30	1.25	1.59	1.83	2.07	2.20	2.26	2.32	2.32
26	1.37	1.37	1.35	1.32	1.28	1.23	1.56	1.80	2.04	2.17	2.23	2.28	2.29
27	1.34	1.35	1.32	1.30	1.25	1.20	1.53	1.77	2.00	2.13	2.20	2.25	2.26
28	1.32	1.33	1.30	1.27	1.23	1.16	1.50	1.74	1.97	2.10	2.16	2.21	2.22
29	1.25	1.25	1.22	1.20	1.15	1.11	1.42	1.65	1.88	2.00	2.07	2.12	2.12
30	1.26	1.27	1.24	1.21	1.17	1.12	1.44	1.67	1.89	2.02	2.08	2.13	2.14
31	1.38	1.39	1.36	1.33	1.29	1.24	1.56	1.80	2.03	2.17	2.24	2.29	2.31
32	1.44	1.45	1.42	1.39	1.35	1.30	1.63	1.88	2.11	2.25	2.33	2.39	2.40
33	1.46	1.47	1.44	1.42	1.37	1.32	1.67	1.91	2.16	2.30	2.37	2.43	2.45
34	1.49	1.51	1.48	1.45	1.41	1.36	1.71	1.97	2.22	2.36	2.44	2.50	2.51
35	1.49	1.51	1.48	1.45	1.41	1.36	1.73	1.99	2.25	2.39	2.46	2.52	2.53
36	1.47	1.48	1.45	1.43	1.38	1.33	1.71	1.98	2.24	2.38	2.44	2.50	2.51
37	1.75	1.78	1.75	1.73	1.68	1.63	2.02	2.30	2.59	2.74	2.82	2.90	2.92
38	1.98	2.01	1.99	1.97	1.92	1.86	2.27	2.57	2.86	3.03	3.12	3.21	3.24
39	2.01	2.04	2.02	2.00	1.95	1.89	2.30	2.61	2.91	3.08	3.17	3.26	3.29
40	2.00	2.03	2.01	1.99	1.94	1.88	2.30	2.61	2.91	3.08	3.17	3.25	3.28
41	1.87	1.90	1.88	1.85	1.81	1.75	2.17	2.48	2.78	2.94	3.02	3.11	3.12
42	1.83	1.85	1.83	1.81	1.76	1.70	2.13	2.43	2.73	2.89	2.98	3.04	3.05
43	1.89	1.92	1.90	1.87	1.83	1.77	2.19	2.50	2.80	2.97	3.05	3.12	3.15
44	1.78	1.80	1.78	1.75	1.71	1.65	2.07	2.38	2.68	2.84	2.92	2.98	3.00
45	1.74	1.76	1.73	1.71	1.66	1.61	2.03	2.33	2.62	2.78	2.85	2.92	2.94
46	1.63	1.65	1.62	1.60	1.55	1.50	1.91	2.21	2.50	2.65	2.73	2.79	2.80
47	1.65	1.67	1.64	1.62	1.57	1.52	1.93	2.23	2.52	2.67	2.75	2.81	2.82
48	1.70	1.72	1.70	1.67	1.63	1.57	1.98	2.28	2.57	2.72	2.80	2.86	2.88
49	1.82	1.84	1.82	1.79	1.75	1.69	2.10	2.40	2.70	2.86	2.94	3.01	3.03
50	1.89	1.92	1.90	1.87	1.83	1.77	2.18	2.49	2.79	2.95	3.04	3.11	3.14
51	1.94	1.97	1.95	1.92	1.88	1.82	2.24	2.54	2.85	3.02	3.11	3.16	3.21
52	2.00	2.04	2.02	1.99	1.95	1.88	2.31	2.62	2.93	3.11	3.20	3.28	3.31
53	2.04	2.07	2.05	2.03	1.98	1.92	2.35	2.67	2.99	3.16	3.26	3.34	3.37
54	2.04	2.07	2.05	2.03	1.98	1.92	2.36	2.69	3.01	3.18	3.28	3.36	3.39

TABLE III. (cont.) ELECTRONIC STOPPING POWER OF IONS AT VELOCITY V0
MODIFIED FIRSOV METHOD STOPPING POWER (1E-13 EV-CM2)

TARGET ATOMIC NUMBER	PROJECTILE ATOMIC NUMBER 19	20	21	22	23	24	25	26	27	28	29	30	31
1	.48	.61	.58	.59	.51	.49	.54	.53	.46	.45	.43	.47	.51
2	.44	.58	.55	.57	.48	.46	.51	.50	.44	.43	.41	.45	.49
3	1.23	1.39	1.36	1.37	1.24	1.20	1.27	1.24	1.13	1.11	1.07	1.13	1.21
4	1.32	1.49	1.46	1.47	1.35	1.30	1.37	1.34	1.24	1.21	1.18	1.22	1.30
5	1.28	1.48	1.44	1.47	1.34	1.30	1.37	1.35	1.24	1.22	1.19	1.23	1.33
6	1.21	1.42	1.38	1.41	1.28	1.25	1.32	1.30	1.20	1.18	1.15	1.19	1.26
7	1.14	1.35	1.31	1.34	1.21	1.18	1.25	1.23	1.14	1.12	1.09	1.13	1.20
8	1.10	1.32	1.28	1.31	1.18	1.14	1.22	1.20	1.11	1.08	1.06	1.10	1.16
9	1.05	1.26	1.22	1.26	1.13	1.09	1.17	1.15	1.05	1.03	1.01	1.05	1.11
10	.99	1.20	1.16	1.19	1.07	1.03	1.11	1.09	1.00	.98	.95	.99	1.05
11	1.43	1.64	1.60	1.63	1.50	1.46	1.53	1.51	1.40	1.39	1.34	1.38	1.46
12	1.70	1.92	1.88	1.91	1.77	1.73	1.80	1.77	1.66	1.63	1.59	1.63	1.71
13	1.98	2.22	2.17	2.20	2.05	2.00	2.08	2.05	1.93	1.89	1.85	1.89	1.98
14	2.05	2.30	2.26	2.29	2.14	2.09	2.16	2.13	2.01	1.97	1.93	1.97	2.06
15	2.03	2.29	2.25	2.29	2.13	2.08	2.16	2.13	2.01	1.97	1.93	1.97	2.06
16	2.04	2.32	2.28	2.32	2.16	2.11	2.20	2.17	2.04	2.01	1.97	2.01	2.10
17	1.97	2.27	2.22	2.26	2.10	2.05	2.14	2.11	1.99	1.96	1.92	1.96	2.05
18	1.90	2.26	2.15	2.20	2.03	1.99	2.08	2.05	1.93	1.91	1.87	1.91	1.99
19	2.26	2.57	2.52	2.57	2.40	2.35	2.45	2.42	2.29	2.25	2.21	2.25	2.34
20	2.53	2.84	2.79	2.84	2.67	2.62	2.71	2.68	2.54	2.51	2.46	2.50	2.59
21	2.52	2.83	2.79	2.84	2.66	2.61	2.70	2.67	2.54	2.50	2.45	2.49	2.59
22	2.46	2.78	2.73	2.78	2.61	2.56	2.65	2.62	2.49	2.45	2.40	2.44	2.54
23	2.41	2.73	2.68	2.73	2.55	2.50	2.60	2.56	2.43	2.48	2.35	2.39	2.48
24	2.26	2.57	2.52	2.57	2.40	2.35	2.44	2.41	2.28	2.25	2.20	2.24	2.33
25	2.30	2.61	2.56	2.61	2.44	2.39	2.48	2.45	2.32	2.28	2.24	2.28	2.37
26	2.27	2.57	2.52	2.57	2.40	2.35	2.44	2.41	2.28	2.25	2.20	2.25	2.33
27	2.24	2.54	2.49	2.54	2.37	2.32	2.41	2.38	2.25	2.21	2.17	2.21	2.30
28	2.20	2.50	2.45	2.49	2.33	2.28	2.37	2.34	2.21	2.17	2.13	2.17	2.26
29	2.10	2.39	2.34	2.39	2.22	2.17	2.26	2.23	2.10	2.07	2.03	2.07	2.15
30	2.11	2.40	2.35	2.40	2.23	2.18	2.27	2.24	2.12	2.08	2.04	2.08	2.17
31	2.28	2.58	2.53	2.57	2.40	2.35	2.44	2.41	2.28	2.25	2.20	2.24	2.33
32	2.38	2.68	2.63	2.68	2.51	2.45	2.54	2.51	2.38	2.34	2.29	2.34	2.43
33	2.43	2.73	2.69	2.73	2.56	2.51	2.60	2.57	2.43	2.40	2.35	2.39	2.48
34	2.49	2.81	2.76	2.81	2.64	2.58	2.68	2.64	2.51	2.47	2.42	2.46	2.56
35	2.51	2.84	2.79	2.84	2.66	2.61	2.70	2.67	2.54	2.50	2.45	2.49	2.59
36	2.49	2.83	2.77	2.83	2.65	2.60	2.70	2.66	2.53	2.49	2.44	2.48	2.58
37	2.90	3.26	3.20	3.26	3.08	3.02	3.12	3.08	2.94	2.90	2.85	2.89	2.99
38	3.22	3.59	3.54	3.61	3.41	3.35	3.46	3.42	3.27	3.23	3.17	3.21	3.31
39	3.28	3.65	3.60	3.67	3.47	3.41	3.52	3.48	3.33	3.29	3.23	3.27	3.37
40	3.27	3.65	3.60	3.67	3.47	3.41	3.52	3.48	3.33	3.29	3.23	3.27	3.37
41	3.10	3.49	3.43	3.50	3.30	3.24	3.35	3.32	3.17	3.13	3.07	3.11	3.22
42	3.04	3.43	3.38	3.45	3.25	3.19	3.30	3.27	3.12	3.08	3.02	3.06	3.17
43	3.13	3.52	3.46	3.53	3.33	3.28	3.39	3.35	3.20	3.16	3.11	3.15	3.25
44	2.98	3.37	3.31	3.38	3.18	3.13	3.24	3.20	3.06	3.02	2.96	3.00	3.11
45	2.92	3.31	3.25	3.32	3.12	3.07	3.18	3.14	3.00	2.96	2.90	2.94	3.05
46	2.78	3.17	3.11	3.18	2.98	2.92	3.03	3.00	2.86	2.82	2.77	2.80	2.91
47	2.80	3.18	3.12	3.19	2.99	2.94	3.05	3.02	2.87	2.83	2.78	2.87	2.92
48	2.86	3.24	3.18	3.25	3.05	3.00	3.11	3.07	2.93	2.89	2.84	2.88	2.98
49	3.01	3.40	3.34	3.41	3.21	3.16	3.26	3.23	3.08	3.04	2.99	3.03	3.13
50	3.12	3.51	3.45	3.52	3.32	3.27	3.37	3.34	3.19	3.15	3.09	3.13	3.24
51	3.19	3.58	3.53	3.60	3.40	3.34	3.45	3.41	3.26	3.22	3.17	3.20	3.31
52	3.30	3.69	3.64	3.71	3.51	3.45	3.56	3.52	3.37	3.33	3.27	3.31	3.41
53	3.36	3.76	3.70	3.78	3.57	3.51	3.63	3.59	3.44	3.39	3.33	3.37	3.48
54	3.37	3.78	3.73	3.80	3.59	3.54	3.65	3.61	3.46	3.41	3.36	3.39	3.50

TABLE III. (cont.) ELECTRONIC STOPPING POWER OF IONS AT VELOCITY V0
MODIFIED FIRSOV METHOD STOPPING POWER (1E-13 EV-CM2)

TARGET ATOMIC NUMBER	PROJECTILE ATOMIC NUMBER 32	33	34	35	36	37	38	39	40	41	42	43	44
1	.59	.64	.67	.69	.70	.70	.84	.94	.88	.81	.79	.84	.76
2	.56	.61	.63	.65	.66	.65	.81	.92	.85	.77	.75	.81	.73
3	1.33	1.43	1.50	1.57	1.61	1.62	1.81	1.95	1.90	1.82	1.79	1.85	1.75
4	1.43	1.53	1.60	1.68	1.72	1.74	1.96	2.12	2.05	1.98	1.94	2.02	1.91
5	1.43	1.52	1.58	1.65	1.69	1.70	1.94	2.12	2.04	1.95	1.92	2.00	1.89
6	1.38	1.47	1.52	1.58	1.61	1.62	1.87	2.06	1.97	1.86	1.84	1.93	1.82
7	1.32	1.40	1.46	1.51	1.54	1.54	1.80	1.99	1.89	1.78	1.76	1.84	1.73
8	1.29	1.37	1.42	1.47	1.50	1.50	1.76	1.96	1.85	1.74	1.72	1.81	1.69
9	1.23	1.31	1.37	1.42	1.44	1.44	1.70	1.89	1.79	1.68	1.65	1.74	1.63
10	1.17	1.25	1.30	1.35	1.37	1.37	1.63	1.82	1.72	1.60	1.58	1.67	1.56
11	1.59	1.68	1.75	1.82	1.86	1.87	2.13	2.33	2.24	2.14	2.11	2.20	2.09
12	1.85	1.96	2.04	2.12	2.17	2.19	2.46	2.67	2.58	2.48	2.46	2.55	2.43
13	2.13	2.25	2.34	2.43	2.49	2.52	2.81	3.03	2.95	2.86	2.83	2.93	2.81
14	2.21	2.33	2.43	2.52	2.58	2.62	2.93	3.16	3.08	2.98	2.95	3.06	2.93
15	2.22	2.34	2.42	2.52	2.58	2.61	2.93	3.17	3.08	2.97	2.95	3.06	2.94
16	2.26	2.38	2.46	2.55	2.61	2.64	2.98	3.23	3.13	3.01	3.00	3.11	2.98
17	2.21	2.33	2.41	2.50	2.55	2.57	2.92	3.18	3.07	2.94	2.92	3.04	2.91
18	2.16	2.28	2.36	2.44	2.48	2.50	2.86	3.13	3.00	2.87	2.85	2.97	2.84
19	2.51	2.64	2.73	2.83	2.89	2.91	3.29	3.57	3.45	3.32	3.30	3.43	3.30
20	2.77	2.90	3.00	3.11	3.17	3.21	3.59	3.89	3.77	3.64	3.63	3.76	3.62
21	2.76	2.90	3.00	3.10	3.17	3.20	3.59	3.88	3.77	3.63	3.62	3.75	3.62
22	2.71	2.85	2.94	3.04	3.11	3.14	3.53	3.82	3.70	3.57	3.56	3.69	3.55
23	2.66	2.79	2.89	2.99	3.05	3.08	3.46	3.76	3.64	3.50	3.49	3.62	3.48
24	2.50	2.63	2.73	2.82	2.88	2.91	3.29	3.57	3.45	3.32	3.30	3.43	3.30
25	2.54	2.67	2.76	2.86	2.92	2.95	3.33	3.61	3.50	3.36	3.35	3.48	3.34
26	2.51	2.63	2.73	2.82	2.89	2.92	3.29	3.57	3.45	3.32	3.31	3.43	3.30
27	2.47	2.60	2.69	2.78	2.85	2.88	3.24	3.52	3.41	3.28	3.26	3.39	3.25
28	2.43	2.55	2.65	2.74	2.80	2.83	3.20	3.47	3.36	3.23	3.22	3.34	3.21
29	2.32	2.44	2.53	2.63	2.69	2.72	3.07	3.34	3.23	3.11	3.09	3.21	3.08
30	2.33	2.45	2.54	2.64	2.70	2.73	3.08	3.35	3.24	3.11	3.10	3.22	3.09
31	2.50	2.63	2.72	2.82	2.88	2.92	3.28	3.55	3.44	3.32	3.31	3.43	3.30
32	2.60	2.73	2.83	2.93	2.99	3.03	3.40	3.68	3.57	3.45	3.43	3.56	3.42
33	2.65	2.79	2.89	2.99	3.06	3.09	3.47	3.75	3.64	3.52	3.51	3.63	3.50
34	2.74	2.87	2.97	3.08	3.15	3.19	3.57	3.86	3.75	3.62	3.61	3.74	3.60
35	2.77	2.90	3.00	3.11	3.18	3.22	3.61	3.91	3.79	3.66	3.65	3.78	3.65
36	2.76	2.90	3.00	3.10	3.17	3.20	3.61	3.92	3.79	3.65	3.64	3.78	3.64
37	3.18	3.33	3.44	3.55	3.63	3.68	4.10	4.43	4.31	4.18	4.17	4.31	4.17
38	3.51	3.66	3.78	3.91	3.99	4.05	4.49	4.83	4.71	4.58	4.57	4.72	4.55
39	3.57	3.73	3.85	3.97	4.06	4.12	4.57	4.91	4.79	4.66	4.65	4.81	4.67
40	3.58	3.73	3.85	3.98	4.06	4.11	4.57	4.93	4.80	4.66	4.66	4.81	4.67
41	3.42	3.58	3.69	3.81	3.89	3.94	4.40	4.75	4.62	4.47	4.46	4.62	4.47
42	3.37	3.53	3.64	3.76	3.84	3.88	4.35	4.70	4.56	4.41	4.40	4.56	4.41
43	3.46	3.61	3.73	3.85	3.93	3.98	4.44	4.80	4.66	4.51	4.50	4.67	4.51
44	3.31	3.47	3.58	3.70	3.78	3.82	4.28	4.64	4.50	4.34	4.33	4.49	4.34
45	3.25	3.41	3.52	3.64	3.71	3.75	4.22	4.57	4.43	4.27	4.26	4.42	4.27
46	3.11	3.26	3.37	3.49	3.56	3.60	4.06	4.41	4.27	4.10	4.10	4.26	4.10
47	3.13	3.28	3.39	3.51	3.58	3.61	4.08	4.43	4.28	4.12	4.11	4.27	4.12
48	3.18	3.34	3.45	3.56	3.64	3.68	4.14	4.49	4.35	4.18	4.18	4.34	4.18
49	3.34	3.49	3.60	3.72	3.80	3.84	4.31	4.66	4.52	4.37	4.36	4.52	4.37
50	3.44	3.60	3.71	3.84	3.92	3.96	4.43	4.79	4.65	4.49	4.49	4.65	4.50
51	3.51	3.67	3.79	3.92	4.00	4.04	4.51	4.87	4.74	4.58	4.58	4.74	4.59
52	3.62	3.78	3.90	4.03	4.12	4.16	4.64	5.00	4.87	4.72	4.72	4.88	4.73
53	3.69	3.85	3.97	4.10	4.19	4.24	4.72	5.09	4.96	4.80	4.80	4.97	4.82
54	3.71	3.88	4.00	4.13	4.22	4.27	4.76	5.13	4.99	4.84	4.84	5.01	4.85

TABLE III. (cont) ELECTRONIC STOPPING POWER OF IONS AT VELOCITY V0
MODIFIED FIRSOV METHOD STOPPING POWER (1E-13 EV-CM2)

TARGET ATOMIC NUMBER	PROJECTILE ATOMIC NUMBER 45	46	47	48	49	50	51	52	53	54
1	.80	.71	.68	.72	.77	.85	.91	.95	1.00	1.03
2	.77	.68	.65	.72	.74	.82	.88	.92	.96	.98
3	1.79	1.67	1.62	1.67	1.73	1.83	1.92	2.00	2.09	2.16
4	1.96	1.83	1.77	1.82	1.88	1.99	2.09	2.17	2.25	2.33
5	1.95	1.82	1.77	1.82	1.88	2.00	2.09	2.16	2.24	2.31
6	1.88	1.75	1.70	1.76	1.82	1.93	2.03	2.09	2.17	2.22
7	1.80	1.67	1.62	1.68	1.74	1.86	1.95	2.02	2.09	2.14
8	1.76	1.63	1.58	1.64	1.71	1.83	1.92	1.98	2.06	2.10
9	1.69	1.57	1.52	1.58	1.65	1.76	1.85	1.92	1.99	2.04
10	1.62	1.49	1.45	1.51	1.57	1.69	1.78	1.84	1.91	1.96
11	2.15	2.02	1.96	2.02	2.09	2.21	2.30	2.38	2.46	2.52
12	2.50	2.36	2.30	2.36	2.43	2.55	2.65	2.73	2.82	2.89
13	2.87	2.73	2.66	2.72	2.79	2.92	3.02	3.11	3.21	3.29
14	3.00	2.85	2.79	2.85	2.92	3.05	3.16	3.24	3.35	3.43
15	3.01	2.85	2.79	2.85	2.93	3.06	3.17	3.26	3.36	3.44
16	3.05	2.90	2.84	2.90	2.98	3.12	3.23	3.32	3.42	3.50
17	2.99	2.83	2.77	2.84	2.92	3.06	3.18	3.27	3.37	3.44
18	2.92	2.76	2.70	2.77	2.85	3.00	3.11	3.20	3.31	3.39
19	3.38	3.22	3.15	3.22	3.30	3.45	3.58	3.67	3.78	3.86
20	3.71	3.54	3.47	3.54	3.63	3.78	3.91	4.01	4.12	4.21
21	3.70	3.53	3.47	3.54	3.62	3.77	3.93	4.03	4.11	4.20
22	3.64	3.47	3.40	3.47	3.56	3.71	3.84	3.94	4.05	4.14
23	3.57	3.40	3.34	3.41	3.49	3.64	3.77	3.87	3.98	4.07
24	3.38	3.22	3.15	3.22	3.30	3.46	3.58	3.68	3.79	3.87
25	3.42	3.26	3.19	3.26	3.35	3.50	3.62	3.72	3.83	3.91
26	3.38	3.22	3.15	3.22	3.30	3.45	3.58	3.68	3.78	3.87
27	3.34	3.17	3.11	3.18	3.26	3.41	3.53	3.63	3.74	3.82
28	3.29	3.13	3.06	3.13	3.21	3.36	3.48	3.58	3.68	3.76
29	3.16	3.00	2.93	3.00	3.08	3.23	3.35	3.44	3.55	3.63
30	3.16	3.01	2.94	3.01	3.09	3.24	3.36	3.45	3.55	3.63
31	3.38	3.22	3.15	3.22	3.30	3.44	3.56	3.66	3.77	3.85
32	3.50	3.34	3.27	3.34	3.42	3.57	3.69	3.79	3.90	3.99
33	3.58	3.42	3.35	3.42	3.50	3.65	3.77	3.87	3.98	4.07
34	3.69	3.52	3.45	3.52	3.61	3.76	3.89	3.99	4.10	4.19
35	3.73	3.57	3.50	3.57	3.65	3.81	3.94	4.04	4.15	4.24
36	3.73	3.56	3.49	3.56	3.65	3.81	3.94	4.04	4.16	4.25
37	4.26	4.09	4.02	4.09	4.18	4.34	4.48	4.59	4.71	4.81
38	4.68	4.50	4.42	4.50	4.59	4.76	4.90	5.01	5.14	5.24
39	4.76	4.58	4.51	4.58	4.67	4.85	4.99	5.10	5.23	5.34
40	4.77	4.58	4.51	4.59	4.68	4.85	5.00	5.11	5.24	5.35
41	4.57	4.39	4.31	4.39	4.49	4.66	4.81	4.93	5.06	5.16
42	4.51	4.33	4.25	4.33	4.43	4.61	4.75	4.87	5.00	5.10
43	4.62	4.43	4.35	4.44	4.53	4.71	4.86	4.98	5.11	5.21
44	4.44	4.26	4.18	4.26	4.36	4.54	4.69	4.81	4.94	5.04
45	4.37	4.18	4.11	4.19	4.29	4.47	4.62	4.74	4.87	4.97
46	4.20	4.02	3.94	4.03	4.12	4.31	4.45	4.57	4.70	4.80
47	4.22	4.03	3.96	4.04	4.14	4.32	4.47	4.58	4.72	4.81
48	4.29	4.10	4.03	4.11	4.20	4.39	4.53	4.65	4.78	4.88
49	4.47	4.29	4.21	4.29	4.39	4.57	4.72	4.83	4.97	5.07
50	4.60	4.42	4.34	4.42	4.52	4.70	4.85	4.97	5.10	5.20
51	4.70	4.51	4.43	4.51	4.61	4.79	4.94	5.06	5.19	5.30
52	4.83	4.65	4.57	4.65	4.75	4.93	5.08	5.20	5.33	5.44
53	4.92	4.73	4.66	4.74	4.84	5.02	5.17	5.29	5.43	5.53
54	4.96	4.77	4.69	4.77	4.87	5.06	5.21	5.33	5.47	5.57

TABLE III. (cont.) ELECTRONIC STOPPING POWER OF IONS AT VELOCITY V0
MODIFIED FIRSOV METHOD STOPPING POWER (1E-13 EV-CM2)

TARGET ATOMIC NUMBER	PROJECTILE ATOMIC NUMBER 55	56	57	58	59	60	61	62	63	64	65	66	67
1	.99	1.16	1.14	1.12	1.26	1.07	1.20	1.03	1.26	1.04	1.11	1.00	1.07
2	.94	1.13	1.09	1.09	1.23	1.04	1.18	1.00	1.24	1.02	1.10	.98	1.06
3	2.12	2.36	2.36	2.30	2.48	2.23	2.40	2.15	2.48	2.18	2.25	2.11	2.19
4	2.30	2.56	2.56	2.50	2.70	2.42	2.62	2.35	2.70	2.38	2.46	2.30	2.39
5	2.27	2.55	2.54	2.49	2.71	2.42	2.63	2.35	2.72	2.38	2.48	2.31	2.41
6	2.19	2.48	2.45	2.42	2.65	2.35	2.57	2.28	2.66	2.31	2.42	2.25	2.36
7	2.10	2.40	2.36	2.34	2.58	2.28	2.50	2.21	2.59	2.24	2.35	2.17	2.29
8	2.07	2.37	2.33	2.31	2.55	2.24	2.47	2.17	2.56	2.20	2.32	2.14	2.26
9	2.00	2.30	2.26	2.24	2.48	2.17	2.40	2.11	2.49	2.14	2.26	2.07	2.19
10	1.92	2.22	2.17	2.16	2.40	2.09	2.32	2.02	2.41	2.05	2.17	1.99	2.11
11	2.48	2.80	2.77	2.74	2.98	2.66	2.89	2.59	2.99	2.62	2.73	2.55	2.66
12	2.85	3.18	3.16	3.12	3.37	3.04	3.28	2.96	3.38	2.99	3.11	2.92	3.03
13	3.26	3.60	3.59	3.53	3.80	3.45	3.70	3.37	3.81	3.41	3.52	3.32	3.43
14	3.40	3.75	3.74	3.69	3.97	3.60	3.87	3.52	3.98	3.56	3.67	3.47	3.58
15	3.41	3.78	3.76	3.71	4.00	3.63	3.90	3.54	4.01	3.58	3.71	3.49	3.62
16	3.47	3.85	3.83	3.78	4.09	3.70	3.98	3.61	4.10	3.65	3.79	3.56	3.69
17	3.41	3.81	3.77	3.73	4.04	3.65	3.94	3.56	4.06	3.60	3.74	3.51	3.65
18	3.34	3.75	3.71	3.67	3.99	3.59	3.88	3.49	4.01	3.54	3.69	3.45	3.60
19	3.83	4.25	4.22	4.17	4.51	4.08	4.39	3.99	4.52	4.03	4.18	3.94	4.09
20	4.17	4.61	4.58	4.53	4.87	4.44	4.76	4.34	4.89	4.39	4.54	4.29	4.44
21	4.17	4.61	4.57	4.53	4.87	4.43	4.76	4.33	4.89	4.38	4.54	4.29	4.44
22	4.10	4.54	4.51	4.46	4.81	4.37	4.69	4.27	4.83	4.32	4.47	4.22	4.37
23	4.03	4.47	4.44	4.39	4.73	4.30	4.62	4.20	4.75	4.25	4.40	4.15	4.30
24	3.84	4.27	4.23	4.19	4.53	4.10	4.42	4.00	4.55	4.05	4.20	3.95	4.10
25	3.88	4.31	4.27	4.23	4.57	4.14	4.46	4.04	4.59	4.09	4.24	3.99	4.14
26	3.83	4.26	4.23	4.18	4.52	4.09	4.41	3.99	4.54	4.04	4.19	3.95	4.09
27	3.79	4.21	4.17	4.13	4.46	4.04	4.35	3.94	4.48	3.99	4.14	3.90	4.04
28	3.73	4.15	4.12	4.07	4.40	3.98	4.29	3.89	4.42	3.93	4.08	3.84	3.98
29	3.60	4.01	3.98	3.94	4.26	3.84	4.15	3.75	4.28	3.80	3.94	3.70	3.85
30	3.60	4.01	3.98	3.94	4.26	3.85	4.15	3.75	4.28	3.80	3.94	3.71	3.85
31	3.82	4.23	4.20	4.16	4.48	4.07	4.37	3.97	4.50	4.02	4.16	3.92	4.06
32	3.95	4.37	4.35	4.30	4.63	4.21	4.52	4.11	4.65	4.16	4.30	4.06	4.20
33	4.04	4.46	4.44	4.39	4.72	4.30	4.61	4.20	4.74	4.25	4.39	4.15	4.29
34	4.16	4.59	4.56	4.52	4.86	4.42	4.74	4.32	4.88	4.37	4.52	4.27	4.42
35	4.21	4.66	4.63	4.58	4.93	4.48	4.81	4.38	4.95	4.43	4.59	4.33	4.48
36	4.22	4.67	4.64	4.59	4.95	4.49	4.83	4.39	4.97	4.44	4.60	4.34	4.50
37	4.78	5.25	5.23	5.17	5.54	5.07	5.42	4.96	5.57	5.02	5.18	4.91	5.07
38	5.21	5.70	5.68	5.62	6.00	5.51	5.87	5.40	6.03	5.46	5.62	5.35	5.51
39	5.30	5.81	5.78	5.72	6.12	5.62	5.99	5.51	6.14	5.56	5.73	5.45	5.61
40	5.32	5.83	5.80	5.74	6.14	5.63	6.01	5.52	6.17	5.58	5.75	5.47	5.64
41	5.13	5.64	5.61	5.55	5.96	5.45	5.82	5.33	5.98	5.39	5.57	5.28	5.45
42	5.07	5.59	5.55	5.50	5.91	5.39	5.77	5.28	5.93	5.34	5.52	5.23	5.40
43	5.18	5.71	5.67	5.62	6.03	5.51	5.89	5.39	6.06	5.45	5.64	5.34	5.52
44	5.01	5.53	5.49	5.44	5.86	5.33	5.72	5.22	5.88	5.28	5.46	5.16	5.34
45	4.94	5.46	5.42	5.37	5.78	5.26	5.65	5.15	5.81	5.21	5.39	5.09	5.27
46	4.77	5.29	5.25	5.20	5.61	5.09	5.48	4.98	5.64	5.04	5.22	4.92	5.11
47	4.78	5.31	5.26	5.22	5.63	5.11	5.49	4.99	5.65	5.05	5.24	4.94	5.12
48	4.85	5.37	5.33	5.28	5.69	5.17	5.56	5.06	5.72	5.12	5.30	5.00	5.18
49	5.04	5.56	5.52	5.47	5.88	5.36	5.75	5.25	5.91	5.31	5.49	5.19	5.37
50	5.17	5.70	5.66	5.61	6.02	5.50	5.88	5.38	6.05	5.44	5.62	5.33	5.51
51	5.27	5.79	5.76	5.70	6.12	5.59	5.98	5.48	6.15	5.54	5.72	5.42	5.60
52	5.41	5.94	5.91	5.85	6.27	5.74	6.13	5.62	6.30	5.68	5.87	5.57	5.74
53	5.50	6.04	6.01	5.95	6.37	5.84	6.23	5.72	6.40	5.78	5.97	5.66	5.84
54	5.54	6.09	6.05	6.00	6.42	5.88	6.28	5.77	6.45	5.83	6.01	5.71	5.89

TABLE III. (cont.) ELECTRONIC STOPPING POWER OF IONS AT VELOCITY V0
MODIFIED FIRSOV METHOD STOPPING POWER (1E-13 EV-CM2)

TARGET ATOMIC NUMBER	PROJECTILE ATOMIC NUMBER 68	69	70	71	72	73	74	75	76	77	78	79	80
1	1.05	1.04	1.02	1.00	1.02	1.03	1.03	1.03	1.02	.93	.84	.82	.87
2	1.04	1.03	1.01	.99	1.01	1.02	1.01	1.01	.99	.90	.81	.79	.84
3	2.15	2.12	2.09	2.06	2.10	2.13	2.14	2.14	2.14	2.02	1.91	1.88	1.94
4	2.35	2.32	2.29	2.25	2.30	2.32	2.34	2.34	2.33	2.21	2.10	2.07	2.13
5	2.37	2.34	2.31	2.28	2.32	2.34	2.35	2.35	2.34	2.22	2.10	2.07	2.14
6	2.32	2.29	2.26	2.24	2.27	2.29	2.29	2.29	2.28	2.15	2.03	2.00	2.07
7	2.26	2.23	2.20	2.17	2.20	2.22	2.22	2.22	2.20	2.07	1.95	1.92	1.99
8	2.23	2.20	2.17	2.14	2.17	2.19	2.19	2.18	2.17	2.03	1.91	1.88	1.95
9	2.16	2.13	2.10	2.08	2.11	2.12	2.12	2.12	2.10	1.97	1.84	1.81	1.88
10	2.08	2.05	2.02	1.99	2.02	2.04	2.04	2.04	2.02	1.88	1.76	1.73	1.80
11	2.63	2.59	2.56	2.53	2.57	2.59	2.60	2.60	2.59	2.45	2.32	2.29	2.37
12	2.99	2.95	2.92	2.88	2.92	2.95	2.96	2.97	2.96	2.82	2.69	2.66	2.74
13	3.39	3.35	3.31	3.27	3.32	3.35	3.37	3.38	3.37	3.23	3.10	3.07	3.15
14	3.54	3.50	3.46	3.42	3.47	3.50	3.52	3.53	3.52	3.38	3.25	3.21	3.29
15	3.57	3.53	3.49	3.45	3.50	3.53	3.55	3.55	3.55	3.40	3.26	3.23	3.31
16	3.65	3.61	3.57	3.53	3.58	3.61	3.62	3.63	3.62	3.46	3.32	3.29	3.38
17	3.61	3.57	3.52	3.49	3.53	3.56	3.57	3.57	3.57	3.40	3.26	3.23	3.31
18	3.55	3.51	3.47	3.43	3.48	3.50	3.51	3.51	3.50	3.33	3.19	3.15	3.24
19	4.04	4.00	3.95	3.91	3.96	3.99	4.01	4.01	4.00	3.83	3.68	3.65	3.74
20	4.39	4.34	4.30	4.25	4.30	4.34	4.36	4.37	4.36	4.19	4.04	4.01	4.10
21	4.39	4.34	4.29	4.25	4.30	4.34	4.35	4.36	4.36	4.18	4.03	4.00	4.09
22	4.32	4.28	4.23	4.19	4.24	4.27	4.29	4.30	4.29	4.12	3.96	3.93	4.03
23	4.25	4.21	4.16	4.12	4.17	4.20	4.22	4.22	4.22	4.04	3.89	3.86	3.95
24	4.06	4.01	3.97	3.92	3.97	4.00	4.02	4.02	4.02	3.84	3.69	3.66	3.75
25	4.10	4.05	4.01	3.96	4.01	4.05	4.06	4.07	4.06	3.89	3.73	3.70	3.79
26	4.05	4.00	3.96	3.91	3.97	4.00	4.01	4.02	4.01	3.84	3.69	3.65	3.75
27	4.00	3.95	3.91	3.86	3.91	3.95	3.96	3.97	3.96	3.79	3.64	3.61	3.70
28	3.94	3.89	3.85	3.81	3.86	3.89	3.91	3.91	3.90	3.74	3.59	3.55	3.64
29	3.80	3.76	3.71	3.67	3.72	3.75	3.77	3.77	3.76	3.60	3.45	3.42	3.51
30	3.80	3.76	3.72	3.67	3.72	3.75	3.77	3.77	3.77	3.60	3.45	3.42	3.51
31	4.02	3.97	3.93	3.88	3.94	3.97	3.99	3.99	3.99	3.82	3.68	3.64	3.73
32	4.15	4.11	4.06	4.02	4.07	4.11	4.13	4.13	4.13	3.96	3.82	3.78	3.87
33	4.24	4.20	4.15	4.11	4.16	4.20	4.22	4.22	4.22	4.05	3.90	3.87	3.96
34	4.37	4.32	4.27	4.23	4.28	4.32	4.34	4.35	4.34	4.17	4.02	3.99	4.09
35	4.43	4.38	4.34	4.29	4.35	4.38	4.40	4.41	4.40	4.23	4.08	4.04	4.14
36	4.45	4.40	4.35	4.30	4.36	4.39	4.41	4.42	4.41	4.23	4.08	4.04	4.14
37	5.01	4.96	4.91	4.86	4.92	4.96	4.99	5.00	5.00	4.82	4.66	4.63	4.73
38	5.45	5.40	5.34	5.29	5.36	5.40	5.43	5.44	5.44	5.26	5.10	5.07	5.18
39	5.56	5.50	5.45	5.39	5.46	5.50	5.53	5.55	5.55	5.36	5.20	5.17	5.28
40	5.58	5.52	5.47	5.41	5.48	5.52	5.55	5.56	5.56	5.37	5.21	5.18	5.29
41	5.40	5.34	5.29	5.23	5.30	5.34	5.36	5.37	5.37	5.17	5.01	4.97	5.08
42	5.35	5.29	5.24	5.18	5.25	5.29	5.31	5.32	5.31	5.12	4.95	4.91	5.02
43	5.46	5.40	5.35	5.30	5.36	5.40	5.42	5.43	5.43	5.23	5.06	5.02	5.14
44	5.29	5.23	5.18	5.13	5.19	5.23	5.25	5.26	5.25	5.05	4.88	4.84	4.95
45	5.22	5.16	5.11	5.06	5.12	5.16	5.18	5.18	5.18	4.98	4.80	4.77	4.88
46	5.05	5.00	4.94	4.89	4.95	4.99	5.01	5.01	5.01	4.80	4.63	4.59	4.70
47	5.06	5.01	4.96	4.90	4.96	5.00	5.02	5.03	5.02	4.82	4.64	4.61	4.72
48	5.13	5.07	5.02	4.97	5.03	5.07	5.09	5.09	5.09	4.89	4.71	4.68	4.79
49	5.32	5.26	5.21	5.15	5.21	5.25	5.28	5.29	5.28	5.08	4.91	4.87	4.99
50	5.45	5.39	5.34	5.28	5.35	5.39	5.41	5.42	5.42	5.22	5.05	5.01	5.13
51	5.54	5.49	5.43	5.38	5.44	5.48	5.51	5.52	5.52	5.32	5.14	5.11	5.22
52	5.69	5.63	5.57	5.52	5.58	5.63	5.65	5.66	5.66	5.47	5.29	5.26	5.37
53	5.78	5.72	5.67	5.61	5.68	5.72	5.75	5.76	5.76	5.56	5.39	5.36	5.47
54	5.83	5.77	5.71	5.66	5.72	5.77	5.80	5.81	5.81	5.61	5.43	5.40	5.52

TABLE III. (cont). ELECTRONIC STOPPING POWER OF IONS AT VELOCITY V0
MODIFIED FIRSOV METHOD STOPPING POWER (1E-13 EV-CM2)

TARGET ATOMIC NUMBER	PROJECTILE ATOMIC NUMBER 81	82	83	84	85	86	87	88	89	90	91	92
1	.92	1.01	1.08	1.13	1.18	1.21	1.24	1.43	1.60	1.65	1.67	1.53
2	.89	.98	1.05	1.11	1.15	1.17	1.19	1.40	1.58	1.62	1.64	1.50
3	2.01	2.13	2.23	2.33	2.41	2.40	2.54	2.80	3.04	3.12	3.18	2.95
4	2.21	2.33	2.44	2.53	2.62	2.69	2.76	3.05	3.30	3.39	3.46	3.21
5	2.21	2.35	2.46	2.55	2.62	2.69	2.75	3.05	3.32	3.41	3.47	3.23
6	2.15	2.28	2.39	2.48	2.56	2.62	2.66	2.98	3.26	3.34	3.39	3.16
7	2.07	2.21	2.32	2.41	2.48	2.53	2.58	2.90	3.19	3.26	3.31	3.08
8	2.03	2.17	2.28	2.37	2.44	2.50	2.54	2.87	3.17	3.24	3.28	3.06
9	1.96	2.10	2.22	2.31	2.38	2.43	2.47	2.80	3.10	3.17	3.21	2.99
10	1.88	2.02	2.13	2.22	2.29	2.34	2.38	2.71	3.01	3.07	3.11	2.89
11	2.45	2.59	2.71	2.81	2.89	2.95	3.00	3.35	3.65	3.73	3.79	3.54
12	2.82	2.97	3.10	3.20	3.28	3.36	3.42	3.77	4.09	4.18	4.24	3.98
13	3.24	3.39	3.52	3.63	3.72	3.80	3.87	4.24	4.58	4.68	4.75	4.47
14	3.39	3.55	3.68	3.80	3.89	3.98	4.05	4.43	4.78	4.88	4.96	4.67
15	3.41	3.58	3.71	3.83	3.93	4.01	4.08	4.47	4.83	4.94	5.01	4.72
16	3.48	3.65	3.79	3.91	4.01	4.09	4.16	4.57	4.94	5.05	5.12	4.83
17	3.41	3.59	3.74	3.86	3.95	4.04	4.10	4.53	4.90	5.01	5.08	4.78
18	3.34	3.53	3.67	3.79	3.89	3.97	4.04	4.47	4.86	4.96	5.03	4.73
19	3.85	4.04	4.19	4.32	4.43	4.51	4.59	5.04	5.44	5.55	5.63	5.31
20	4.21	4.40	4.56	4.70	4.81	4.90	4.98	5.44	5.86	5.98	6.06	5.73
21	4.20	4.40	4.56	4.69	4.80	4.90	4.97	5.44	5.86	5.98	6.07	5.73
22	4.14	4.33	4.49	4.62	4.73	4.83	4.90	5.37	5.79	5.91	6.00	5.66
23	4.06	4.26	4.42	4.55	4.66	4.75	4.83	5.29	5.71	5.83	5.91	5.58
24	3.86	4.05	4.21	4.34	4.45	4.54	4.61	5.08	5.49	5.61	5.69	5.36
25	3.90	4.10	4.25	4.38	4.49	4.58	4.65	5.12	5.53	5.65	5.73	5.40
26	3.86	4.05	4.20	4.33	4.44	4.53	4.60	5.06	5.48	5.59	5.67	5.35
27	3.81	4.00	4.15	4.28	4.39	4.48	4.55	5.01	5.41	5.53	5.61	5.29
28	3.75	3.94	4.09	4.22	4.33	4.41	4.49	4.94	5.34	5.46	5.54	5.22
29	3.61	3.80	3.95	4.08	4.18	4.27	4.34	4.78	5.18	5.30	5.38	5.06
30	3.62	3.80	3.95	4.08	4.18	4.27	4.34	4.78	5.18	5.29	5.37	5.05
31	3.84	4.03	4.18	4.30	4.41	4.50	4.57	5.02	5.42	5.54	5.62	5.30
32	3.98	4.17	4.32	4.45	4.56	4.65	4.72	5.17	5.58	5.70	5.78	5.46
33	4.07	4.26	4.42	4.55	4.66	4.75	4.82	5.28	5.69	5.81	5.90	5.57
34	4.20	4.39	4.55	4.68	4.79	4.89	4.97	5.43	5.85	5.97	6.06	5.73
35	4.25	4.45	4.61	4.75	4.86	4.96	5.04	5.51	5.94	6.06	6.15	5.81
36	4.26	4.46	4.62	4.76	4.87	4.97	5.05	5.53	5.97	6.09	6.18	5.84
37	4.85	5.06	5.23	5.37	5.49	5.60	5.68	6.19	6.64	6.77	6.87	6.51
38	5.30	5.52	5.69	5.84	5.97	6.08	6.17	6.69	7.16	7.30	7.40	7.03
39	5.41	5.62	5.81	5.96	6.09	6.20	6.29	6.82	7.30	7.44	7.55	7.17
40	5.42	5.64	5.82	5.97	6.11	6.22	6.31	6.85	7.33	7.48	7.58	7.20
41	5.21	5.44	5.62	5.77	5.91	6.01	6.11	6.65	7.14	7.28	7.38	7.00
42	5.15	5.38	5.57	5.72	5.85	5.96	6.05	6.60	7.10	7.24	7.34	6.95
43	5.27	5.50	5.69	5.84	5.97	6.08	6.18	6.73	7.23	7.38	7.48	7.09
44	5.09	5.32	5.50	5.66	5.79	5.90	5.99	6.55	7.05	7.19	7.29	6.90
45	5.01	5.24	5.43	5.58	5.72	5.83	5.92	6.48	6.98	7.12	7.22	6.83
46	4.84	5.07	5.25	5.41	5.54	5.65	5.74	6.30	6.80	6.94	7.04	6.64
47	4.85	5.08	5.27	5.42	5.55	5.66	5.75	6.31	6.81	6.95	7.05	6.66
48	4.92	5.15	5.33	5.49	5.62	5.73	5.82	6.38	6.88	7.02	7.12	6.73
49	5.12	5.35	5.54	5.65	5.82	5.93	6.03	6.59	7.09	7.23	7.34	6.94
50	5.26	5.49	5.68	5.83	5.97	6.08	6.17	6.73	7.24	7.38	7.49	7.09
51	5.36	5.59	5.78	5.94	6.07	6.18	6.28	6.84	7.35	7.49	7.60	7.20
52	5.51	5.74	5.93	6.09	6.23	6.34	6.44	7.00	7.51	7.66	7.77	7.36
53	5.61	5.84	6.04	6.20	6.33	6.45	6.54	7.11	7.63	7.78	7.89	7.48
54	5.65	5.89	6.08	6.25	6.38	6.50	6.60	7.17	7.69	7.84	7.95	7.54

TABLE III. (cont.) ELECTRONIC STOPPING POWER OF IONS AT VELOCITY V0
MODIFIED FIRSOV METHOD STOPPING POWER (1E-13 EV-CM2)

TARGET ATOMIC NUMBER	PROJECTILE ATOMIC NUMBER 6	7	8	9	10	11	12	13	14	15	16	17	18
55	2.33	2.37	2.36	2.34	2.29	2.23	2.68	3.02	3.36	3.55	3.65	3.76	3.80
56	2.57	2.62	2.61	2.59	2.54	2.48	2.94	3.29	3.65	3.86	3.98	4.09	4.14
57	2.64	2.69	2.69	2.67	2.62	2.55	3.03	3.38	3.74	3.96	4.08	4.19	4.25
58	2.60	2.65	2.64	2.63	2.58	2.51	2.[illegible]8	3.34	3.70	3.91	4.03	4.14	4.19
59	2.48	2.53	2.52	2.50	2.45	2.38	2.85	3.20	3.55	3.75	3.87	3.98	4.03
60	2.44	2.49	2.43	2.46	2.41	2.35	2.81	3.15	3.50	3.71	3.82	3.93	3.97
61	2.41	2.46	2.44	2.42	2.37	2.31	2.77	3.11	3.46	3.66	3.77	3.88	3.92
62	2.37	2.42	2.41	2.39	2.34	2.27	2.73	3.07	3.41	3.61	3.73	3.83	3.87
63	2.34	2.38	2.37	2.35	2.30	2.23	2.69	3.03	3.37	3.57	3.68	3.78	3.82
64	2.38	2.43	2.42	2.40	2.35	2.28	2.74	3.08	3.43	3.63	3.74	3.84	3.89
65	2.27	2.32	2.31	2.28	2.23	2.17	2.62	2.95	3.28	3.48	3.59	3.69	3.73
66	2.24	2.29	2.27	2.25	2.20	2.14	2.58	2.91	3.24	3.44	3.55	3.65	3.69
67	2.22	2.26	2.24	2.22	2.17	2.11	2.55	2.88	3.21	3.40	3.51	3.61	3.65
68	2.19	2.23	2.22	2.19	2.15	2.08	2.52	2.84	3.17	3.36	3.47	3.57	3.61
69	2.16	2.21	2.19	2.17	2.12	2.05	2.49	2.81	3.13	3.32	3.43	3.53	3.57
70	2.14	2.18	2.16	2.14	2.09	2.03	2.46	2.78	3.10	3.29	3.40	3.49	3.53
71	2.21	2.26	2.24	2.22	2.17	2.10	2.54	2.86	3.19	3.38	3.49	3.59	3.63
72	2.23	2.28	2.26	2.24	2.19	2.12	2.56	2.89	3.22	3.41	3.52	3.62	3.66
73	2.23	2.27	2.26	2.24	2.19	2.12	2.57	2.89	3.22	3.42	3.53	3.62	3.66
74	2.22	2.26	2.25	2.22	2.18	2.11	2.56	2.89	3.22	3.41	3.52	3.61	3.65
75	2.20	2.24	2.22	2.20	2.15	2.09	2.54	2.87	3.20	3.39	3.50	3.59	3.63
76	2.17	2.21	2.19	2.17	2.12	2.06	2.51	2.85	3.18	3.37	3.47	3.56	3.[illegible]
77	2.14	2.17	2.15	2.14	2.09	2.03	2.48	2.81	3.15	3.34	3.44	3.53	3.56
78	2.05	2.08	2.07	2.04	2.00	1.93	2.39	2.72	3.05	3.24	3.33	3.42	3.45
79	2.00	2.04	2.02	2.00	1.95	1.89	2.34	2.67	3.00	3.19	3.25	3.36	3.39
80	2.02	2.05	2.03	2.01	1.96	1.90	2.36	2.69	3.02	3.21	3.30	3.38	3.41
81	2.15	2.18	2.17	2.14	2.10	2.03	2.49	2.83	3.17	3.36	3.46	3.54	3.58
82	2.24	2.28	2.26	2.24	2.19	2.13	2.59	2.93	3.28	3.47	3.57	3.67	3.7[illegible]
83	2.30	2.35	2.34	2.32	2.27	2.20	2.67	3.02	3.36	3.56	3.67	3.76	3.80
84	2.42	2.47	2.46	2.44	2.39	2.32	2.80	3.16	3.51	3.72	3.83	3.93	3.98
85	2.39	2.43	2.42	2.40	2.36	2.29	2.77	3.13	3.48	3.69	3.8[illegible]	3.90	3.94
86	2.40	2.45	2.43	2.42	2.37	2.30	2.79	3.15	3.51	3.72	3.83	3.93	3.97
87	2.73	2.79	2.79	2.77	2.72	2.65	3.15	3.53	3.91	4.13	4.25	4.37	4.43
88	2.99	3.06	3.06	3.05	3.00	2.93	3.44	3.82	4.21	4.45	4.59	4.72	4.79
89	3.11	3.19	3.19	3.18	3.13	3.06	3.58	3.97	4.37	4.62	4.75	4.90	4.97
90	3.17	3.25	3.26	3.25	3.20	3.12	3.65	4.05	4.46	4.71	4.85	4.99	5.07
91	3.07	3.14	3.14	3.13	3.08	3.01	3.54	3.93	4.34	4.58	4.72	4.85	4.92
92	3.03	3.10	3.10	3.09	3.04	2.97	3.49	3.89	4.29	4.53	4.67	4.80	4.57
93	2.98	3.05	3.05	3.04	2.99	2.92	3.45	3.84	4.25	4.48	4.62	4.75	4.81
94	2.87	2.93	2.93	2.92	2.87	2.80	3.32	3.70	4.10	4.34	4.47	4.59	4.65
95	2.81	2.88	2.87	2.86	2.81	2.74	3.26	3.64	4.04	4.27	4.[illegible]	4.52	4.[illegible]6
96	2.85	2.91	2.91	2.90	2.85	2.78	3.30	3.69	4.08	4.31	4.45	4.57	4.63
97	2.71	2.77	2.77	2.75	2.70	2.63	3.14	3.52	3.91	4.14	4.26	4.38	4.44
98	2.66	2.72	2.72	2.70	2.65	2.58	3.09	3.47	3.85	4.08	4.20	4.32	4.37
99	2.62	2.68	2.67	2.65	2.60	2.53	3.04	3.41	3.79	4.01	4.14	4.25	4.3[illegible]
100	2.57	2.63	2.62	2.61	2.56	2.49	2.99	3.36	3.73	3.95	4.09	4.19	4.24
101	2.53	2.59	2.58	2.56	2.51	2.44	2.94	3.3[illegible]	3.68	3.89	4.02	4.13	4.19
102	2.49	2.55	2.54	2.52	2.47	2.40	2.89	3.26	3.62	3.84	3.95	4.07	4.12

TABLE III. (cont.) ELECTRONIC STOPPING POWER OF IONS AT VELOCITY VO
MODIFIED FIRSOV METHOD STOPPING POWER (1E-13 EV-CM2)

TARGET ATOMIC NUMBER	PROJECTILE ATOMIC NUMBER 19	20	21	22	23	24	25	26	27	28	29	30	31
55	3.80	4.22	4.17	4.24	4.03	3.97	4.09	4.04	3.89	3.84	3.77	3.81	[illegible]
56	4.14	4.58	4.53	4.61	4.40	4.33	4.45	4.40	4.24	4.19	4.12	4.16	4.27
57	4.25	4.70	4.65	4.73	4.52	4.45	4.57	4.52	4.36	4.31	4.24	4.27	[illegible]
58	4.20	4.64	4.59	4.67	4.46	4.39	4.51	4.47	4.30	4.25	4.18	4.22	[illegible]
59	4.03	4.46	4.41	4.49	4.28	4.21	4.33	4.29	4.12	4.07	4.01	4.04	[illegible]
60	3.97	4.41	4.36	4.44	4.22	4.16	4.27	4.23	4.07	4.02	3.96	3.99	4.10
61	3.92	4.35	[illegible]	4.38	4.17	4.11	4.22	4.18	4.02	3.97	3.90	3.94	[illegible]
62	3.87	4.30	4.25	4.33	4.11	4.05	4.17	4.12	3.96	3.91	3.85	3.89	3.99
63	3.82	4.25	4.19	4.27	4.06	4.00	4.11	4.07	3.91	3.86	3.80	3.84	3.94
64	3.88	4.31	4.26	4.34	4.13	4.07	4.16	4.14	3.98	3.93	3.86	3.90	4.01
65	3.73	4.15	4.09	4.17	3.96	3.90	4.01	3.97	3.81	3.77	3.70	3.74	3.85
66	3.68	4.10	4.05	4.12	3.91	3.85	3.97	3.93	3.77	3.72	3.66	3.69	[illegible]
67	3.64	4.06	4.00	4.08	3.87	3.81	3.92	3.88	3.72	3.67	3.61	3.65	3.75
68	3.60	4.01	3.96	4.03	3.83	3.77	3.88	3.84	3.68	3.63	3.57	3.61	3.71
69	3.56	3.97	3.92	3.99	3.78	3.72	3.83	3.79	3.64	3.59	3.53	3.56	3.67
70	3.52	3.93	3.88	3.95	3.74	3.68	3.79	3.75	3.60	3.55	3.49	3.52	3.63
71	3.62	4.03	3.98	4.05	3.85	3.79	3.89	3.85	3.70	3.65	3.59	3.62	3.73
72	3.65	4.06	4.01	4.08	3.88	3.82	3.93	3.69	3.73	3.68	3.62	3.66	3.76
73	3.65	4.07	4.02	4.09	3.88	3.83	3.94	3.90	3.74	3.69	3.63	3.67	3.77
74	3.64	4.06	4.01	4.09	3.88	3.82	3.93	3.89	3.73	3.68	3.62	3.66	3.77
75	3.62	4.04	3.99	4.07	3.85	3.80	3.91	3.87	3.71	3.67	3.60	3.64	3.75
76	3.59	4.01	3.96	4.04	3.82	3.76	3.88	3.84	3.68	3.64	3.59	3.61	3.72
77	3.55	3.98	3.92	4.00	3.78	3.73	3.84	3.80	3.65	3.60	3.54	3.58	3.69
78	3.43	3.86	3.80	3.88	3.67	3.61	3.73	3.69	3.53	3.49	3.43	3.47	3.59
79	3.37	3.80	3.74	3.82	3.61	3.55	3.67	3.63	3.47	3.43	3.37	3.41	3.52
80	3.39	3.82	3.76	3.84	3.63	3.57	3.69	3.65	3.50	3.45	3.39	3.43	3.54
81	3.56	4.00	3.94	4.02	3.81	3.75	3.87	3.83	3.67	3.62	3.56	3.60	3.71
82	3.69	4.13	4.07	4.16	3.94	3.88	4.00	3.96	3.80	3.75	3.69	3.73	3.84
83	3.79	4.24	4.18	4.26	4.05	3.99	4.10	4.06	3.90	3.86	3.79	3.83	3.94
84	3.97	4.43	4.37	4.45	4.24	4.17	4.29	4.25	4.09	4.04	3.98	4.01	4.12
85	3.93	4.39	4.33	4.41	4.19	4.13	4.25	4.21	4.05	4.00	3.94	3.97	4.09
86	3.96	4.42	4.36	4.45	4.23	4.17	4.29	4.25	4.09	4.04	3.97	4.01	4.12
87	4.43	4.91	4.86	4.95	4.72	4.66	4.78	4.74	4.57	4.52	4.45	4.48	4.59
88	4.80	5.29	5.24	5.33	5.11	5.04	5.17	5.12	4.95	4.89	4.82	4.85	4.96
89	4.99	5.49	5.44	5.53	5.31	5.24	5.36	5.32	5.14	5.08	5.01	5.04	5.16
90	5.08	5.59	5.54	5.65	5.41	5.35	5.47	5.43	5.25	5.19	5.12	5.15	5.25
91	4.94	5.44	5.39	5.49	5.26	5.19	5.32	5.27	5.10	5.04	4.97	5.00	5.12
92	4.88	5.39	5.34	5.44	5.20	5.14	5.27	5.22	5.04	4.99	4.92	4.95	5.06
93	4.82	5.33	5.27	5.37	5.14	5.08	5.21	5.16	4.98	4.93	4.86	4.89	5.01
94	4.66	5.16	5.10	5.20	4.97	4.91	5.03	4.99	4.82	4.76	4.69	4.72	4.84
95	4.58	5.08	5.03	5.12	4.89	4.83	4.96	4.91	4.74	4.69	4.61	4.65	4.76
96	4.63	5.13	5.08	5.18	4.94	4.88	5.01	4.96	4.79	4.74	4.66	4.70	4.81
97	4.44	4.93	4.87	4.97	4.74	4.68	4.80	4.76	4.59	4.54	4.47	4.50	4.62
98	4.37	4.86	4.80	4.90	4.67	4.61	4.73	4.69	4.52	4.47	4.40	4.43	4.55
99	4.30	4.79	4.73	4.83	4.60	4.54	4.66	4.62	4.45	4.40	4.33	4.35	4.48
100	4.24	4.72	4.66	4.76	4.53	4.47	4.59	4.55	4.38	4.33	4.26	4.30	4.41
101	4.17	4.65	4.60	4.69	4.46	4.40	4.52	4.48	4.31	4.26	4.19	4.23	4.34
102	4.12	4.59	4.54	4.63	4.40	4.34	4.46	4.42	4.25	4.20	4.14	4.17	4.28

TABLE III. (cont.) ELECTRONIC STOPPING POWER OF IONS AT VELOCITY VO
MODIFIED FIRSOV METHOD STOPPING POWER (1E-15 EV-CM2)

TARGET ATOMIC NUMBER	PROJECTILE ATOMIC NUMBER 32	33	34	35	36	37	38	39	40	41	42	43	44
55	4.14	4.31	4.44	4.58	4.68	4.75	5.25	5.64	5.51	5.36	5.37	5.54	5.39
56	4.49	4.67	4.81	4.95	5.07	5.14	5.66	6.06	5.94	5.80	5.81	5.99	5.84
57	4.61	4.79	4.93	5.09	5.20	5.27	5.80	6.21	6.09	5.95	5.96	6.15	5.99
58	4.56	4.74	4.88	5.03	5.14	5.21	5.74	6.15	6.02	5.88	5.89	6.08	5.92
59	4.38	4.55	4.69	4.84	4.95	5.01	5.53	5.94	5.81	5.67	5.67	5.85	5.7[illegible]
60	4.32	4.50	4.64	4.78	4.89	4.96	5.47	5.87	5.75	5.60	5.61	5.79	5.64
61	4.27	4.44	4.58	4.73	4.83	4.90	5.41	5.81	5.68	5.54	5.54	5.72	5.57
62	4.22	4.39	4.53	4.67	4.77	4.84	5.35	5.75	5.62	5.47	5.48	5.66	5.51
63	4.16	4.34	4.47	4.62	4.72	4.78	5.29	5.69	5.56	5.41	5.42	5.59	5.44
64	4.23	4.41	4.54	4.69	4.79	4.85	5.37	5.77	5.64	5.49	5.50	5.67	5.52
65	4.06	4.24	4.37	4.51	4.61	4.67	5.18	5.57	5.44	5.29	5.30	5.47	5.32
66	4.02	4.19	4.32	4.45	4.56	4.62	5.12	5.51	5.38	5.24	5.24	5.41	5.26
67	3.97	4.14	4.27	4.41	4.51	4.57	5.07	5.45	5.33	5.18	5.19	5.36	5.21
68	3.93	4.10	4.23	4.37	4.46	4.52	5.02	5.40	5.27	5.13	5.13	5.30	5.15
69	3.88	4.05	4.18	4.32	4.42	4.48	4.97	5.35	5.22	5.08	5.08	5.2[illegible]	5.10
70	3.84	4.01	4.14	4.28	4.37	4.43	4.92	5.30	5.17	5.03	5.03	5.2[illegible]	5.05
71	3.94	4.11	4.24	4.38	4.48	4.54	5.03	5.41	5.29	5.15	5.15	5.32	5.17
72	3.98	4.15	4.28	4.42	4.52	4.58	5.07	5.46	5.33	5.18	5.19	5.36	5.21
73	3.99	4.16	4.29	4.43	4.53	4.59	5.09	5.47	5.34	5.20	5.20	5.37	5.22
74	3.98	4.16	4.29	4.43	4.52	4.58	5.08	5.47	5.34	5.19	5.19	5.37	5.21
75	3.97	4.14	4.27	4.41	4.50	4.56	5.07	5.46	5.32	5.17	5.17	5.35	5.19
76	3.94	4.11	4.24	4.38	4.48	4.53	5.04	5.43	5.29	5.14	5.14	5.32	5.16
77	3.91	4.08	4.21	4.34	4.44	4.49	5.00	5.40	5.26	5.09	5.10	5.26	5.12
78	3.80	3.97	4.09	4.23	4.32	4.37	4.88	5.27	5.13	4.96	4.97	5.14	4.99
79	3.74	3.91	4.03	4.17	4.26	4.31	4.82	5.21	5.06	4.90	4.90	5.08	4.92
80	3.76	3.93	4.06	4.19	4.28	4.33	4.85	5.24	5.09	4.92	4.93	5.11	4.94
81	3.93	4.11	4.24	4.38	4.47	4.52	5.04	5.44	5.30	5.13	5.13	5.31	5.15
82	4.06	4.24	4.37	4.51	4.61	4.66	5.19	5.59	5.45	5.28	5.29	5.47	5.31
83	4.17	4.34	4.48	4.62	4.72	4.78	5.31	5.72	5.58	5.41	5.42	5.60	5.44
84	4.36	4.54	4.67	4.82	4.93	4.99	5.53	5.95	5.81	5.64	5.65	5.84	5.68
85	4.32	4.50	4.63	4.78	4.88	4.95	5.48	5.90	5.76	5.59	5.60	5.79	5.63
86	4.35	4.54	4.67	4.82	4.93	4.99	5.53	5.95	5.81	5.64	5.65	5.84	5.68
87	4.83	5.02	5.17	5.33	5.44	5.52	6.08	6.51	6.38	6.22	6.24	6.43	6.28
88	5.21	5.40	5.55	5.72	5.84	5.93	6.51	6.95	6.83	6.68	6.70	6.90	6.74
89	5.40	5.60	5.76	5.93	6.06	6.14	6.73	7.19	7.06	6.91	6.94	7.14	6.99
90	5.51	5.71	5.87	6.04	6.17	6.26	6.86	7.33	7.20	7.05	7.07	7.29	7.13
91	5.36	5.56	5.72	5.89	6.02	6.10	6.69	7.16	7.02	6.87	6.89	7.10	6.94
92	5.31	5.51	5.67	5.84	5.96	6.04	6.64	7.10	6.96	6.81	6.83	7.04	6.88
93	5.25	5.45	5.61	5.77	5.90	5.98	6.57	7.04	6.90	6.74	6.76	6.97	6.81
94	5.09	5.28	5.43	5.60	5.72	5.80	6.39	6.84	6.70	6.54	6.56	6.77	6.61
95	5.01	5.21	5.36	5.52	5.64	5.71	6.30	6.76	6.61	6.45	6.47	6.68	6.51
96	5.06	5.26	5.41	5.57	5.69	5.77	6.36	6.82	6.67	6.51	6.53	6.74	6.57
97	4.86	5.05	5.20	5.35	5.48	5.55	6.13	6.58	6.44	6.27	6.29	6.50	6.33
98	4.79	4.98	5.13	5.29	5.40	5.48	6.05	6.50	6.36	6.19	6.21	6.41	6.25
99	4.72	4.91	5.06	5.22	5.33	5.40	5.97	6.42	6.27	6.11	6.12	6.32	6.16
100	4.65	4.84	4.98	5.14	5.25	5.32	5.89	6.34	6.19	6.02	6.04	6.24	6.08
101	4.58	4.77	4.91	5.07	5.18	5.25	5.82	6.25	6.11	5.94	5.95	6.15	5.99
102	4.52	4.71	4.85	5.01	5.12	5.18	5.74	6.18	6.04	5.87	5.88	6.08	5.92

TABLE III. (cont.) ELECTRONIC STOPPING POWER OF IONS AT VELOCITY V0
MODIFIED FIRSOV METHOD STOPPING POWER (1E-13 EV-CM2)

TARGET ATOMIC NUMBER	PROJECTILE ATOMIC NUMBER 45	46	47	48	49	50	51	52	53	54
55	5.50	5.31	5.23	5.31	5.41	5.60	5.75	5.88	6.02	6.13
56	5.95	5.76	5.68	5.76	5.86	6.05	6.21	6.33	6.48	6.60
57	6.11	5.92	5.83	5.92	6.02	6.21	6.37	6.50	6.65	6.77
58	6.04	5.85	5.77	5.85	5.95	6.14	6.30	6.43	6.58	6.70
59	5.82	5.62	5.54	5.63	5.73	5.92	6.07	6.20	6.35	6.46
60	5.75	5.56	5.48	5.56	5.66	5.85	6.01	6.13	6.28	6.40
61	5.68	5.49	5.41	5.49	5.59	5.78	5.94	6.07	6.21	6.33
62	5.62	5.43	5.35	5.43	5.53	5.72	5.87	6.00	6.14	6.26
63	5.55	5.36	5.28	5.37	5.47	5.65	5.81	5.93	6.08	6.19
64	5.63	5.44	5.35	5.45	5.55	5.74	5.89	6.02	6.16	6.28
65	5.43	5.24	5.15	5.24	5.34	5.53	5.68	5.81	5.95	6.05
66	5.37	5.18	5.10	5.18	5.28	5.47	5.62	5.75	5.89	6.00
67	5.32	5.13	5.05	5.13	5.23	5.41	5.56	5.69	5.83	5.94
68	5.26	5.07	4.99	5.07	5.17	5.36	5.51	5.63	5.77	5.88
69	5.21	5.02	4.94	5.02	5.12	5.30	5.45	5.58	5.72	5.83
70	5.16	4.97	4.89	4.97	5.07	5.25	5.40	5.52	5.66	5.77
71	5.28	5.09	5.01	5.09	5.19	5.37	5.52	5.64	5.79	5.90
72	5.32	5.13	5.05	5.13	5.23	5.41	5.56	5.69	5.83	5.94
73	5.33	5.14	5.05	5.14	5.24	5.43	5.58	5.70	5.85	5.95
74	5.32	5.13	5.05	5.14	5.24	5.42	5.58	5.70	5.85	5.95
75	5.30	5.11	5.03	5.12	5.22	5.41	5.56	5.69	5.83	5.94
76	5.27	5.08	5.00	5.08	5.19	5.38	5.53	5.66	5.80	5.91
77	5.23	5.04	4.96	5.04	5.15	5.34	5.50	5.62	5.77	5.83
78	5.10	4.90	4.82	4.91	5.01	5.21	5.37	5.49	5.64	5.75
79	5.03	4.83	4.75	4.64	4.95	5.14	5.33	5.42	5.57	5.68
80	5.06	4.86	4.78	4.87	4.97	5.17	5.33	5.46	5.60	5.71
81	5.27	5.07	4.99	5.08	5.18	5.38	5.54	5.67	5.81	5.93
82	5.43	5.23	5.15	5.24	5.34	5.54	5.70	5.83	5.98	6.09
83	5.56	5.36	5.28	5.37	5.48	5.67	5.83	5.96	6.11	6.23
84	5.80	5.60	5.52	5.61	5.72	5.92	6.08	6.21	6.37	6.48
85	5.75	5.55	5.47	5.56	5.67	5.87	6.03	6.16	6.31	6.43
86	5.80	5.60	5.52	5.61	5.72	5.92	6.08	6.22	6.37	6.49
87	6.40	6.20	6.12	6.21	6.31	6.52	6.68	6.82	6.98	7.10
88	6.87	6.67	6.59	6.68	6.78	6.99	7.16	7.33	7.46	7.59
89	7.12	6.92	6.83	6.92	7.03	7.24	7.41	7.55	7.71	7.85
90	7.26	7.06	6.97	7.07	7.18	7.39	7.56	7.70	7.67	8.00
91	7.08	6.87	6.79	6.88	6.99	7.20	7.37	7.52	7.68	7.81
92	7.01	6.81	6.72	6.82	6.93	7.14	7.31	7.46	7.62	7.75
93	6.94	6.74	6.65	6.75	6.86	7.07	7.24	7.39	7.55	7.68
94	6.74	6.53	6.45	6.54	6.65	6.87	7.04	7.18	7.34	7.47
95	6.64	6.44	6.35	6.45	6.56	6.77	6.95	7.09	7.25	7.38
96	6.70	6.50	6.41	6.51	6.62	6.83	7.01	7.15	7.31	7.44
97	6.46	6.26	6.17	6.27	6.38	6.59	6.76	6.90	7.06	7.19
98	6.37	6.17	6.09	6.18	6.29	6.50	6.67	6.81	6.97	7.10
99	6.29	6.08	6.00	6.09	6.20	6.41	6.58	6.72	6.88	7.01
100	6.20	6.00	5.92	6.01	6.12	6.33	6.50	6.64	6.82	6.92
101	6.12	5.92	5.83	5.93	6.04	6.24	6.41	6.55	6.71	6.83
102	6.04	5.84	5.76	5.85	5.96	6.17	6.34	6.47	6.63	6.7[illegible]

TABLE III. (cont.) ELECTRONIC STOPPING POWER OF IONS AT VELOCITY V0
MODIFIED FIRSOV METHOD STOPPING POWER (1E-13 EV-CM2)

TARGET ATOMIC NUMBER	PROJECTILE ATOMIC NUMBER 55	56	57	58	59	60	61	62	63	64	65	66	67
55	6.10	6.66	6.63	6.57	7.00	6.45	6.86	6.33	7.03	6.40	6.58	6.27	6.45
56	6.57	7.13	7.12	7.05	7.49	6.93	7.35	6.80	7.53	6.87	7.06	6.74	6.93
57	6.74	7.31	7.29	7.22	7.68	7.10	7.53	6.98	7.71	7.05	7.24	6.92	7.10
58	6.67	7.24	7.22	7.15	7.61	7.03	7.46	6.91	7.64	6.98	7.17	6.85	7.03
59	6.43	7.00	6.98	6.91	7.36	6.79	7.21	6.67	7.39	6.74	6.93	6.61	6.79
60	6.37	6.93	6.91	6.84	7.29	6.73	7.14	6.60	7.32	6.67	6.86	6.54	6.73
61	6.30	6.86	6.84	6.77	7.22	6.66	7.07	6.53	7.25	6.60	6.79	6.47	6.66
62	6.23	6.79	6.77	6.70	7.15	6.59	7.00	6.46	7.18	6.53	6.72	6.40	6.59
63	6.16	6.72	6.70	6.63	7.08	6.52	6.93	6.39	7.11	6.46	6.65	6.34	6.52
64	6.25	6.81	6.79	6.72	7.17	6.61	7.02	6.48	7.20	6.55	6.74	6.42	6.61
65	6.03	6.59	6.57	6.50	6.94	6.39	6.79	6.26	6.97	6.33	6.52	6.21	6.39
66	5.97	6.53	6.50	6.44	6.87	6.32	6.73	6.20	6.90	6.27	6.45	6.14	6.32
67	5.91	6.46	6.44	6.37	6.81	6.26	6.66	6.14	6.84	6.21	6.39	6.08	6.26
68	5.85	6.40	6.38	6.31	6.75	6.20	6.60	6.08	6.78	6.15	6.33	6.02	6.20
69	5.80	6.34	6.32	6.26	6.68	6.14	6.54	6.02	6.72	6.09	6.27	5.97	6.14
70	5.74	6.29	6.26	6.20	6.63	6.09	6.48	5.97	6.66	6.03	6.21	5.91	6.09
71	5.87	6.41	6.39	6.32	6.75	6.21	6.61	6.09	6.79	6.16	6.34	6.03	6.21
72	5.91	6.46	6.44	6.37	6.80	6.26	6.66	6.14	6.83	6.20	6.39	6.08	6.26
73	5.93	6.48	6.46	6.39	6.83	6.28	6.68	6.16	6.86	6.22	6.41	6.10	6.28
74	5.93	6.48	6.46	6.39	6.83	6.28	6.69	6.16	6.86	6.22	6.41	6.10	6.28
75	5.91	6.47	6.44	6.38	6.82	6.27	6.68	6.14	6.85	6.21	6.40	6.09	6.27
76	5.89	6.45	6.42	6.36	6.80	6.24	6.65	6.12	6.83	6.18	6.38	6.06	6.25
77	5.85	6.41	6.38	6.32	6.77	6.21	6.62	6.08	6.80	6.15	6.34	6.02	6.21
78	5.72	6.29	6.25	6.19	6.64	6.08	6.49	5.95	6.67	6.02	6.21	5.89	6.08
79	5.65	6.22	6.18	6.13	6.57	6.01	6.43	5.89	6.61	5.95	6.15	5.83	6.02
80	5.68	6.26	6.22	6.16	6.61	6.04	6.46	5.92	6.64	5.98	6.18	5.86	6.05
81	5.90	6.48	6.44	6.38	6.84	6.26	6.69	6.14	6.87	6.20	6.40	6.08	6.27
82	6.06	6.65	6.61	6.55	7.01	6.43	6.86	6.31	7.04	6.37	6.57	6.25	6.44
83	6.20	6.79	6.76	6.69	7.15	6.57	7.00	6.45	7.19	6.51	6.71	6.39	6.58
84	6.45	7.05	7.02	6.96	7.43	6.84	7.27	6.71	7.46	6.78	6.98	6.64	6.84
85	6.40	7.00	6.97	6.90	7.37	6.78	7.22	6.65	7.41	6.72	6.92	6.59	6.79
86	6.46	7.06	7.03	6.96	7.44	6.84	7.28	6.71	7.47	6.78	6.99	6.65	6.65
87	7.07	7.68	7.66	7.59	8.07	7.47	7.92	7.33	8.11	7.41	7.61	7.27	7.47
88	7.56	8.18	8.16	8.09	8.58	7.96	8.42	7.82	8.62	7.90	8.11	7.76	7.96
89	7.81	8.45	8.43	8.35	8.85	8.23	8.69	8.09	8.89	8.17	8.37	8.02	8.22
90	7.97	8.61	8.59	8.51	9.02	8.38	8.65	8.24	9.06	8.33	8.53	8.18	8.38
91	7.78	8.42	8.40	8.32	8.83	8.20	8.67	8.06	8.87	8.14	8.35	7.99	8.20
92	7.72	8.36	8.34	8.26	8.77	8.14	8.61	8.00	8.81	8.08	8.29	7.93	8.14
93	7.65	8.29	8.27	8.20	8.70	8.07	8.54	7.93	8.74	8.01	8.22	7.86	8.07
94	7.44	8.08	8.06	7.98	8.49	7.86	8.32	7.72	6.53	7.80	8.01	7.65	7.86
95	7.35	7.99	7.96	7.89	8.39	7.76	8.23	7.62	8.43	7.70	7.91	7.56	7.76
96	7.41	8.05	8.03	7.95	8.46	7.83	8.30	7.69	6.50	7.77	7.98	7.62	7.83
97	7.16	7.80	7.77	7.70	8.20	7.57	8.04	7.43	8.24	7.51	7.72	7.37	7.57
98	7.07	7.70	7.68	7.61	8.10	7.48	7.94	7.34	8.14	7.42	7.63	7.28	7.48
99	6.98	7.61	7.58	7.51	8.01	7.39	7.85	7.25	8.05	7.33	7.54	7.19	7.39
100	6.89	7.52	7.49	7.42	7.92	7.30	7.75	7.16	7.95	7.23	7.45	7.10	7.30
101	6.80	7.43	7.40	7.33	7.82	7.20	7.66	7.07	7.86	7.14	7.35	7.01	7.21
102	6.72	7.34	7.32	7.25	7.73	7.12	7.58	6.99	7.77	7.06	7.27	6.93	7.13

TABLE III. (cont.) ELECTRONIC STOPPING POWER OF IONS AT VELOCITY V0
MODIFIED FIRSOV METHOD STOPPING POWER (1E-13 EV-CM2)

TARGET ATOMIC NUMBER	PROJECTILE ATOMIC NUMBER 68	69	70	71	72	73	74	75	76	77	78	79	80
55	6.39	6.33	6.27	6.21	6.28	6.33	6.36	6.38	6.39	6.19	6.02	5.99	6.11
56	6.86	6.80	6.73	6.67	6.75	6.80	6.84	6.86	6.87	6.67	6.58	6.48	6.60
57	7.03	6.97	6.91	6.84	6.92	6.98	7.01	7.04	7.05	6.85	6.68	6.65	6.78
58	6.97	6.90	6.84	6.78	6.85	6.91	6.95	6.97	6.98	6.78	6.60	6.58	6.70
59	6.73	6.66	6.60	6.54	6.62	6.67	6.71	6.73	6.73	6.53	6.36	6.33	6.46
60	6.66	6.60	6.54	6.48	6.55	6.60	6.64	6.66	6.66	6.47	6.29	6.26	6.39
61	6.59	6.53	6.47	6.41	6.48	6.53	6.57	6.59	6.59	6.40	6.22	6.19	6.32
62	6.52	6.46	6.40	6.34	6.41	6.46	6.50	6.52	6.52	6.33	6.15	6.12	6.25
63	6.45	6.39	6.33	6.27	6.34	6.40	6.43	6.45	6.45	6.26	6.08	6.05	6.18
64	6.54	6.48	6.42	6.36	6.43	6.48	6.52	6.54	6.54	6.34	6.17	6.14	6.26
65	6.32	6.26	6.20	6.14	6.21	6.26	6.30	6.32	6.32	6.12	5.95	5.92	6.04
66	6.26	6.20	6.14	6.08	6.15	6.20	6.23	6.25	6.26	6.06	5.89	5.86	5.98
67	6.20	6.14	6.08	6.02	6.09	6.14	6.17	6.19	6.19	6.00	5.83	5.80	5.92
68	6.14	6.08	6.02	5.96	6.03	6.08	6.11	6.13	6.13	5.94	5.77	5.74	5.86
69	6.08	6.02	5.96	5.90	5.97	6.02	6.05	6.07	6.08	5.88	5.71	5.68	5.80
70	6.02	5.96	5.90	5.85	5.92	5.97	6.00	6.02	6.02	5.83	5.66	5.62	5.74
71	6.15	6.09	6.03	5.97	6.04	6.09	6.12	6.14	6.15	5.95	5.78	5.75	5.87
72	6.20	6.13	6.07	6.02	6.09	6.14	6.17	6.19	6.19	6.00	5.82	5.79	5.91
73	6.22	6.15	6.10	6.04	6.11	6.16	6.19	6.21	6.21	6.01	5.84	5.81	5.93
74	6.22	6.16	6.10	6.04	6.11	6.16	6.19	6.21	6.21	6.01	5.84	5.81	5.93
75	6.21	6.15	6.09	6.03	6.10	6.15	6.18	6.19	6.20	5.99	5.82	5.79	5.91
76	6.18	6.12	6.06	6.01	6.07	6.12	6.15	6.17	6.17	5.96	5.79	5.76	5.88
77	6.15	6.09	6.03	5.97	6.04	6.09	6.12	6.13	6.13	5.92	5.74	5.71	5.84
78	6.02	5.96	5.90	5.84	5.91	5.96	5.99	6.00	6.00	5.79	5.61	5.57	5.70
79	5.96	5.90	5.84	5.78	5.85	5.89	5.92	5.93	5.93	5.72	5.53	5.50	5.62
80	5.99	5.93	5.87	5.81	5.88	5.93	5.95	5.96	5.96	5.75	5.57	5.53	5.66
81	6.21	6.15	6.09	6.03	6.10	6.14	6.17	6.19	6.19	5.97	5.79	5.76	5.88
82	6.36	6.31	6.25	6.19	6.26	6.31	6.34	6.36	6.36	6.15	5.96	5.93	6.06
83	6.51	6.45	6.39	6.33	6.40	6.45	6.48	6.50	6.50	6.29	6.10	6.07	6.20
84	6.77	6.71	6.65	6.58	6.66	6.71	6.74	6.76	6.77	6.55	6.37	6.34	6.47
85	6.72	6.66	6.59	6.53	6.61	6.66	6.69	6.71	6.71	6.50	6.31	6.28	6.41
86	6.78	6.72	6.65	6.59	6.67	6.72	6.75	6.77	6.77	6.56	6.37	6.34	6.47
87	7.40	7.33	7.26	7.20	7.28	7.34	7.37	7.40	7.41	7.20	7.01	6.99	7.12
88	7.89	7.82	7.75	7.68	7.76	7.83	7.87	7.90	7.91	7.70	7.52	7.50	7.63
89	8.15	8.08	8.01	7.94	8.02	8.09	8.14	8.17	8.18	7.97	7.79	7.77	7.91
90	8.31	8.23	8.16	8.09	8.18	8.25	8.29	8.32	8.34	8.13	7.95	7.93	8.07
91	8.12	8.05	7.98	7.91	8.00	8.06	8.10	8.13	8.15	7.93	7.75	7.73	7.87
92	8.06	7.99	7.92	7.85	7.94	8.00	8.05	8.07	8.09	7.87	7.69	7.66	7.80
93	8.00	7.92	7.85	7.79	7.87	7.93	7.98	8.00	8.01	7.80	7.61	7.59	7.73
94	7.79	7.71	7.65	7.58	7.66	7.72	7.76	7.79	7.80	7.58	7.40	7.37	7.51
95	7.69	7.62	7.55	7.49	7.57	7.63	7.67	7.69	7.70	7.48	7.30	7.27	7.41
96	7.76	7.69	7.62	7.55	7.63	7.69	7.73	7.76	7.77	7.55	7.36	7.34	7.48
97	7.50	7.43	7.37	7.30	7.38	7.44	7.48	7.50	7.51	7.29	7.10	7.07	7.21
98	7.41	7.34	7.27	7.21	7.29	7.35	7.39	7.41	7.42	7.20	7.01	6.98	7.12
99	7.32	7.25	7.18	7.12	7.20	7.26	7.29	7.32	7.32	7.10	6.92	6.89	7.02
100	7.23	7.16	7.09	7.03	7.11	7.16	7.20	7.22	7.23	7.01	6.83	6.80	6.93
101	7.14	7.07	7.01	6.94	7.02	7.07	7.11	7.13	7.14	6.92	6.73	6.71	6.84
102	7.06	6.99	6.92	6.86	6.94	6.99	7.03	7.05	7.06	6.84	6.65	6.62	6.76

TABLE III. (cont.) ELECTRONIC STOPPING POWER OF IONS AT VELOCITY V0
MODIFIED FIRSOV METHOD STOPPING POWER (1E-13 EV-CM2)

TARGET ATOMIC NUMBER	PROJECTILE ATOMIC NUMBER 81	82	83	84	85	86	87	88	89	90	91	92
55	6.25	6.49	6.69	6.85	7.00	7.12	7.22	7.81	8.33	8.49	8.61	8.19
56	6.74	6.99	7.19	7.36	7.51	7.64	7.75	8.34	8.88	9.05	9.18	8.74
57	6.92	7.17	7.38	7.55	7.70	7.83	7.94	8.54	9.09	9.26	9.39	8.96
58	6.85	7.10	7.30	7.48	7.62	7.75	7.86	8.47	9.02	9.19	9.31	8.88
59	6.60	6.85	7.05	7.22	7.37	7.49	7.60	8.20	8.74	8.91	9.03	8.60
60	6.53	6.78	6.98	7.15	7.29	7.42	7.53	8.13	8.67	8.83	8.95	8.52
61	6.46	6.70	6.91	7.08	7.22	7.35	7.45	8.05	8.59	8.75	8.87	8.45
62	6.39	6.63	6.83	7.00	7.15	7.27	7.38	7.97	8.51	8.67	8.79	8.37
63	6.32	6.56	6.76	6.93	7.07	7.20	7.30	7.90	8.43	8.59	8.72	8.29
64	6.41	6.65	6.85	7.02	7.17	7.29	7.40	8.00	8.54	8.70	8.82	8.39
65	6.18	6.42	6.62	6.79	6.93	7.06	7.16	7.75	8.28	8.44	8.56	8.14
66	6.12	6.36	6.56	6.72	6.87	6.99	7.09	7.68	8.20	8.36	6.48	8.06
67	6.06	6.29	6.49	6.66	6.80	6.92	7.02	7.61	8.13	8.29	8.41	7.99
68	5.99	6.23	6.43	6.59	6.73	6.86	6.96	7.54	8.06	8.22	8.34	7.92
69	5.94	6.17	6.37	6.53	6.67	6.79	6.90	7.47	7.99	8.15	8.27	7.85
70	5.88	6.11	6.31	6.47	6.61	6.73	6.83	7.41	7.93	8.08	8.20	7.79
71	6.01	6.24	6.44	6.60	6.74	6.87	6.97	7.55	8.07	8.23	8.34	7.93
72	6.05	6.29	6.49	6.65	6.79	6.91	7.02	7.60	8.12	8.28	8.40	7.98
73	6.07	6.31	6.51	6.67	6.82	6.94	7.04	7.62	8.15	8.31	8.43	8.01
74	6.07	6.31	6.51	6.68	6.82	6.94	7.04	7.63	8.16	8.32	8.44	8.02
75	6.05	6.29	6.49	6.66	6.80	6.93	7.03	7.62	8.16	8.32	8.44	8.01
76	6.02	6.26	6.47	6.64	6.78	6.90	7.01	7.60	8.14	8.30	8.42	7.99
77	5.96	6.22	6.43	6.60	6.74	6.86	6.97	7.57	8.11	8.27	8.39	7.96
78	5.84	6.09	6.29	6.46	6.60	6.73	6.83	7.43	7.98	8.14	8.25	7.82
79	5.77	6.02	6.22	6.39	6.53	6.66	6.76	7.36	7.91	8.07	8.18	7.75
80	5.80	6.05	6.26	6.43	6.57	6.69	6.80	7.41	7.95	8.11	8.23	7.80
81	6.33	6.28	6.49	6.66	6.81	6.93	7.04	7.65	8.20	8.37	6.48	8.05
82	6.20	6.46	6.66	6.84	6.99	7.11	7.22	7.94	8.39	8.56	8.68	8.24
83	6.35	6.60	6.81	6.99	7.14	7.26	7.37	7.99	8.55	8.72	8.85	8.40
84	6.62	6.88	7.09	7.27	7.42	7.55	7.66	8.29	8.86	9.03	9.16	8.71
85	6.56	6.82	7.03	7.21	7.36	7.49	7.60	8.23	8.80	8.97	9.10	8.65
86	6.62	6.88	7.10	7.27	7.43	7.56	7.67	8.30	3.88	9.05	9.18	8.72
87	7.28	7.54	7.76	7.94	8.10	8.24	8.35	9.00	9.58	9.76	9.93	9.43
88	7.79	8.06	8.28	6.47	8.63	8.77	8.89	9.55	10.14	10.33	10.47	10.00
89	8.07	8.34	8.57	6.76	8.92	9.06	9.19	9.85	10.45	10.64	10.79	10.31
90	8.23	8.51	8.73	8.93	9.09	9.24	9.36	10.03	10.64	10.83	10.98	10.50
91	8.03	8.31	8.53	8.73	8.89	9.04	9.16	9.83	10.44	10.63	10.77	10.29
92	7.97	8.24	8.47	6.66	8.83	8.97	9.10	9.77	10.38	10.57	10.71	10.23
93	7.89	8.17	8.40	8.59	8.76	8.90	9.02	9.70	10.30	10.49	10.64	10.16
94	7.67	7.95	8.17	8.37	8.53	6.67	8.79	9.46	10.07	10.26	10.40	9.92
95	7.57	7.85	8.07	8.26	8.43	6.57	8.69	9.36	9.97	10.15	10.30	9.81
96	7.64	7.91	8.14	8.33	8.50	6.64	8.76	9.44	10.04	10.23	10.37	9.89
97	7.37	7.65	7.87	8.06	8.23	6.37	8.49	9.15	9.76	9.94	10.08	9.60
98	7.28	7.55	7.78	7.97	8.13	8.27	8.39	9.05	9.65	9.84	9.98	9.50
99	7.18	7.46	7.68	7.87	8.03	8.17	8.29	8.95	9.55	9.73	9.87	9.39
100	7.09	7.36	7.58	7.77	7.93	8.07	8.19	8.85	9.45	9.63	9.77	9.29
101	7.00	7.27	7.49	7.68	7.84	7.97	8.09	8.75	9.34	9.52	9.66	9.19
102	6.91	7.18	7.40	7.59	7.75	7.88	8.00	8.65	9.24	9.43	9.56	9.09

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